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IN THE

Supreme Court of the United States.

OCTOBER TERM, 1905.

STATE OF MISSOURI,
Complainant,
vs.
STATE OF ILLINOIS and the SANITARY DISTRICT OF CHICAGO,
Defendants.

ORIGINAL No. 4.

REPLY OF DEFENDANTS TO BRIEF AND ARGUMENT OF COMPLAINANT.

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Of Counsel.

THE GUNTHORP-WARREN PRINTING CO., 116 RANDOLPH STREET, CHICAGO

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STATEMENT.

As this is an original case in this Court, we deem it necessary, in presenting the questions involved and the manner in which they arise, to refer to the bill, answer, and evidence introduced by the respective parties. This evidence must be considered in the light of the opinion of this Court when deciding the demurrer to the bill (reported in the 180 U. S., at page 208). We will confine what is to be said on our part more particularly to a reply to the brief and argument presented on behalf of the complainant.

We will first briefly refer to the material allegations in the bill and answer, the ultimate facts, and the law of the case as we understand it.

BILL.

The bill in substance avers that the inhabitants of the State of Missouri, time whereof the memory of man runneth not to the contrary, have used, "for drinking, agricultural, and manufacturing purposes" the water of the Mississippi River, and that such uses "are indispensible to the life and health and business of many thousands of the inhabitants of the State of Missouri and are of great value to your orator as a State;" and "that cities and towns below the mouth of said Illinois River, within the territory of your orator, do and are compelled, by means of water works," etc., "to supply the inhabitants of said cities and towns with an adequate supply of pure and wholesome water, fit and healthful for drinking and all other domestic purposes and uses, from the said Mississippi River," etc.; that in 1889 the State of Illinois enacted a law known as the "Sanitary District Act", etc., under and by which the defendant Sanitary District, a corporation, was organized, etc.; that the City of Chicago is located upon the Chicago River, into which it has constructed divers sewers, by means of which sewage system the sewage of Chicago located largely within the boundaries of said Sanitary District "is led into and flows into the Chicago River and Lake Michigan"; that said Sanitary District, under the supervision and control of the State of Illinois has constructed a channel from the Chicago River in said city and connected it with the Desplaines River, which river empties into the Illinois River, the latter flowing into the Mississippi River at a point about 43 miles above the City of St. Louis, Missouri.

That said channel so constructed by the Sanitary District "cut through the natural ridge or water-shed which divides the basin of Lake Michigan from the basin of the Desplaines and Illinois Rivers and the basin of the Mississippi River" and that "by means of the premises" the defendants now pro-

pose and threaten to receive into said channel or drain the sewage matter and filth of the Sanitary District of Chicago, which embraces nearly the whole City of Chicago and a portion of the County of Cook, etc."

"That if defendants should be permitted to carry their said threats into execution" and cause the said sewage and filth "to flow into the Mississippi River, that the waters of the Mississippi River within the jurisdiction of your orator will of a certainty be poisoned and polluted and rendered wholly unfit and unhealthful for drinking and domestic uses, and will render wholly valueless and entirely worthless the various water works systems of towns and cities on the borders of the State of Missouri," etc. "And that said threatened action of the defendants will amount to a direct and continuing nuisance," etc; that by means of the premises such sewage and filth "will poison and pollute said waters with the germs of diseases of various and many kinds."

That the complainant hath no adequate remedy at law and prays "that the defendants, their officers, agents, servants and employes, may be restrained by injunction issuing out of this court from receiving or permitting any sewage to be received or discharged into the artificial channel or drain and from permitting the same to flow or causing the same to be made to flow through said channel or drain towards and into the Desplaines River" * * * "that the defendant, the State of Illinois, be enjoined and restrained from issuing to its co-defendant permission and authority to do or perform the acts aforesaid" * * * and for such other and further relief as the equity of the case may require and to your Honors may seem meet."

ANSWER.

The answer of the State of Illinois in effect adopts the answer of the Sanitary District, which latter in substance, omitting the formal parts as well as the facts admitted therein, denies that all or any considerable portion of the sewage and drainage of the territory embraced in said district is led into or flows into Lake Michigan by way of the Chicago River; that it has already received into said Drainage Canal the sewage aforesaid, but specifically denies that the same "will pass by the homes of the inhabitants of the State of Missouri, or of the cities and towns and their water works, within said State;" denies "that it will injure the property and business of the cities and towns or that it will establish and create as to them a direct and continuing nuisance with the results in said bill described, or any injurious results;" denies that "it will poison and pollute the waters of the said Mississippi River along the territory of the complainant with germs or diseases of various kinds or with any germs or diseases whatever;" alleges "that in the year 1822 the proper authorities of the United States enacted a law granting to the State of Illinois the right to have a route for a canal connecting the Illinois River with the southern bend of Lake Michigan;" that in the year 1827 a further Act of Congress in aid thereof was passed; that subsequently the State of Illinois entered upon said work and constructed the Canal, in pursuance of said legislation, from "Bridgeport to La Salle upon the Illinois River;" that in the year 1848 a pumping station was established, by means of which the waters from the Chicago River and Lake Michigan were pumped into said Canal, and carried from thence to the Illinois and Mississippi Rivers, and from thence hitherto the said waters have carried the sewage from the City of Chicago to the Illinois River substantially, as to quantity and quality, as com-

plained of in this bill; that the Sanitary District pursuant to its authority, at an expense of many millions of dollars, and with the full knowledge of the complainant, constructed the ditch complained of in this bill in order to obtain a gravity flow of said waters for drainage and sewage purposes.

That it completed said work prior to the filing of complainant's bill, and that the waters of Lake Michigan, including the sewage of the City of Chicago, was turned into the same on January 17, 1900; that the State of Missouri had notice of the premises and the object and purposes of said expenditure; and that by reason of such notice, and the delay in filing its bill of complaint, is guilty of *laches*, has slept upon its rights, if any it had, and is estopped from further urging its cause; "that by the natural law relating to sewage and drains and to running water in large bodies, the said sewage instead of contributing a harmful element, is deprived of all its deleterious qualities by processes of vaporization, attrition, lodgement, absorption, chemical conversion and bacteriological changes, so that in the end the water purifies itself."

FACTS.

The question as to whether or not the sewage from the City of Chicago will materially contaminate the waters of the Mississippi River would seem to be the principal question at issue.

All of the evidence on behalf of the complainant was that of experts. The defendants introduced not only the evidence of many learned and distinguished experts, and the results of experiments both bacteriological and chemical, bearing directly upon the questions at issue, but also the evidence of a large number of non-expert witnesses, who had to do with and who actually used the waters of the Illinois River for years prior and continuously subsequent to the opening of

the Drainage Canal, who were and are residents along the shores of the Illinois River from its source to its confluence with the Mississippi River.

It is manifest from the evidence of the experts introduced by complainants that there is a decided conflict in the evidence and opinions. Some of the experts offered by complainant contend that a sewage polluted stream will not purify itself however long the distance. These experts are largely the so-called epidemiologists, many of whom are engineers interested in the establishment of filtering plants. This character of witnesses seem to be a school by themselves. The others, consisting mainly of bacteriologist and chemist, hold to a directly opposite opinion.

On behalf of the defendants, it was shown by carefully conducted scientific examinations, by and under the direction of the State Board of Health of Illinois, Sanitary District of Chicago, City of Chicago, and University of Illinois for about one year prior to the opening of the Chicago Drainage Canal (including therein the sewage of the City of Chicago complained of in this bill) and for about two years thereafter, as well as, by the undisputed evidence of hundreds of non-expert witnesses (old residents) along and upon the banks of the Illinois River between the confluence of the Desplaines River with the Illinois River and the confluence of the Illinois River within the Mississippi River:

1st. That since the opening of the Canal (including therein the sewage complained of) the waters of the Illinois River from its source to its confluence with the Mississippi River is better and more fit for drinking, domestic, manufacturing and all other useful purposes than it was prior to the opening of said Canal.

2nd. That since the opening of the Drainage Canal more and better fish appear in the Illinois River below the mouth of the Desplaines River than prior thereto.

3rd. That among the inhabitants between said points who have used the water since the opening of the Drainage Canal there has been less typhoid, less malaria, and better health generally than before the opening of said Canal.

4th. That the opening of the Drainage Canal has resulted in the improvement of the waters of the Illinois River for manufacturing and industrial purposes.

5th. That since the opening of the Drainage Canal, the waters of the Illinois River at its confluence with the Mississippi River are better than the waters of the Mississippi or Missouri River for domestic and all other uses.

The defendants introduced the evidence of over three hundred lay witnesses who have resided along the shores of the Illinois River from the mouth of the Desplaines River to the mouth of the Illinois River for many years prior to the opening of the Drainage Canal, and who have continued to reside along and upon the same. These witnesses testified in substance, that the water was better, clearer and purer since the opening of the Canal than it was prior thereto. They also testified that they used the waters of the Illinois River between said points for domestic and manufacturing purposes without any treatment whatever, and that the same was more wholesome for domestic use and better for manufacturing purposes since the opening of the Drainage Canal than it was prior thereto; that among such inhabitants who used said waters between said points there was less typhoid, less malaria, less dysentery, and less sickness of every kind and character than there was prior to the opening of the Canal; that since the opening of the said Canal more and better fish appeared in said river between said points; that large quantities of ice had been annually, during the winters since the opening of the Canal, cut from the waters of the Illinois River above the City of Peoria and used by the inhabitants of the City of Peoria. Among those cutting ice in said Illi-

nois River above Peoria and below the mouth of the Desplaines River, since the opening of said Drainage Canal, were two St. Louis firms extensively engaged in the handling of ice, and that large quantities were taken from said Illinois River immediately above the City of Peoria and conveyed to the City of St. Louis and used for domestic purposes, and that no ill effects upon the inhabitants of the City of St. Louis were occasioned thereby, and that no complaints were made, so far as the testimony discloses, as to the same having caused any diseases whatever among the inhabitants. The evidence of the experts on behalf of the complainant is to the effect that neither the Mississippi nor the Missouri River above the confluence of the Illinois River with the Mississippi River contained water suitable for domestic purposes without filtration or treatment and the necessity of filtration or other treatment, and the cost thereof, would in no manner be enhanced by reason of the waters of the Mississippi River being augemented by the waters from the Illinois River and the Drainage Canal, including therein the sewage of the City of Chicago.

These, being the ultimate facts, which is manifest from a consideration of all the evidence, we take the position that the following propositions of law are sound and apply to the case.

POINTS AND AUTHORITIES.

I.

Municipal authorities have the power to construct and maintain sewerage systems for the health and comfort of the inhabitants thereof, and may discharge the same into navigable streams and waters. It was and is a lawful act for the City of Chicago to discharge its sewers into the Chicago River and the branches thereof.

Am. & Eng. Ency. of Law, 2nd Ed., Vol. 10, pp. 248-249, and notes;

Wm. T. Merrifield v. *City of Worcester*, 110 Mass., 216;

Wm. D. Strobel et al. v. *The Kerr Salt Company*, 164 N. Y. Court of Appeals, 303;

City of Valparaiso v. *Hagen et al.*, 153 Ind., 337;

Hayes v. *Waldron*, 44 N. H., 580, 24 Am. Dec., 105;

Lockwood Co. v. *Lawrence*, 77 Me., 297, 52 Am. Rep., 763;

Tennessee Coal Ect. Co. v. *Hamilton*, 100 Ala., 252, 46 Am. State Rep., 48, 14 South., 167;

Carey v. *Daniels*, 8 Met., 466, 41 Am. Dec., 532;

Townsend v. *Bell*, 42 App. Div., 409, 59 N. Y. Supp., 203;

Red River Roller Mills v. *Wright*, 30 Minn., 249, 44 Am. Rep., 194, 15 N. W., 167;

Hazeltine v. *Case*, 64 Wis., 391, 32 Am. Rep., 715, 1 N. W., 66;

Greene v. *Nunnemacher*, 36 Wis., 50;

Pennsylvania Coal Co. v. *Sanderson*, 113 Pa. St., 126, 57 Am. Rep., 445, 6 Atl., 453;

Morgan v. *Danbury*, 67 Conn., 484, 35 Atl., 499;

Noonan v. *Albany*, 79 N. Y., 470, 35 Am. Rep., 540;
Weston Paper Co. v. *Pope*, 155 Ind., 394, 57 N. E., 719;
Richmond v. *Test*, 18 Ind. App., 482, 48 N. E., 610;
Valparaiso v. *Hagen*, 153 Ind., 337, 74 Am. St. Rep., 305, 54 N. E., 1062;
Barnard v. *Sherley*, 135 Ind., 547, 41 Am. St. Rep., 454, 34 N. E., 600, 35 N. E., 117;
Joplin Consolidated Mineral Co. v. *City of Joplin*, 124 Mo. 129.

II.

The Acts of Congress of 1822 and 1827 duly authorized the State of Illinois to connect by means of a Canal the waters of Lake Michigan with the waters of the Illinois River. Therefore, the connection of the same and the waters thereof, as done, was a lawful act.

Act of Mch. 30th, 1822; 3 Stat. at Large, P. 659;
Act of Mch. 2, 1827; 4th Stat. at Large, P. 234;
Wisconsin v. *Duluth*, 96th U. S., 379.

III.

In an action of this kind where each party produces the evidence of a reasonable number of reputable experts, equally schooled in the questions of science at issue, and such evidence shows an irreconcilable conflict, the evidence of numerous non-expert witnesses (especially if uncontradicted), who from personal experience by the actual use of the water, testify that, before and after the alleged contamination complained of, they continuously used the water for drinking and other domestic uses, and for the making of steam and other manufacturing purposes, and that since the doing of the acts complained of the water has been improved for such and all

other purposes, the evidence of such non-expert witnesses is of more weight than that of such expert evidence, and should control the decision of the case:

Newark Aqueduct Board v. *City of Passaic*, 18 Atl. Rep., 106, 45 N. J. Eq. Rep., 393.

In support of this proposition we also cite:

Rouse v. *Martin*, 75 Ala., 514;

Laughlin v. *President & Trustees of Lamasco City*, 6th Ind., 223;

Wood on Nuisances, Vol. 1, P. 732, Secs. 539-540, especially 539 and last par. of 540;

Wignore on Evidence, Vol. I, Sec. 568 (1904).

IV.

"That an injunction to restrain a nuisance will issue only in cases where the fact of nuisance is made out upon determinate and satisfactory evidence; that if the evidence is conflicting, and the injury doubtful, that conflict and doubt will be a ground for withholding an injunction; and that, where interposition by injunction is sought, to restrain that which it is apprehended will create a nuisance of which its complainant may complain, the proofs must show such a state of facts as will manifest the danger to be real and immediate."

State of Missouri v. *State of Illinois and Sanitary District of Chicago*, 180 U. S., page 248, in support of which we cite,

Story's Equity Jurisprudence, Vol. 2, Sec., 924-924a, 13th Ed.;

Wood on Nuisances, Vol. 1, page 732, Sec. 539, ... Ed.;

Columbia Ave Savings Fund v. *Prison Commissioners of Georgia*, 92 Fed., 801;

Parker v. *Winnipiseogee, C. & W. Co.*, 67 U. S., 344, 555; 17 Law Ed., 333-337;

District Attorney v. *Lynn & Boston R. R. Co.*, 16 Gray (82 Mass.), 245;

Robb v. *Village of LaGrange*, 158 Ill., 21;

Springer v. *Walters*, 139 Ill., 419;

Gallagher v. *Flury*, 57 Atl. Rep. (Md.), 672, quoting *Mayor* v. *Smith*, 64 N. H., 380; 10 Atl. Rep., 709;

Powell v. *Bentley & G. Furniture Co.*, 34 W. Va.; 12 S. E. Rep., 1085;

Dunn v. *City of Austin*, 11 S. W. Rep. (Texas), 1125;

Rouse v. *Martin*, 75 Ala., 514.

ARGUMENT.

The Law of the Case.

I.

Municipal authorities have the power to construct and maintain sewerage systems for the health and comfort of the inhabitants thereof, and may discharge the same into navigable streams and waters. It was and is a lawful act for the City of Chicago to discharge its sewers into Lake Michigan and the Chicago River and the branches thereof:

10 Am. & Eng. Ency. of Law, Second Edition, page 248.

"A municipal corporation in the lawful exercise of its power to construct a system of sewerage may make use of a natural stream for the purpose of discharging sewers into it, without ordinarily incurring any liability on account of the pollution of such stream * * * the municipal corporation having the right to construct sewers and drains may lawfully so construct them as to discharge sewage into the sea or other navigable water."

This quotation is sustained by numerous authorities cited in the notes.

In the case of *Merrifield v. City of Worcester*, 110 Mass., 216, plaintiff complains that the city had discharged sewage into a stream known as Millbrook, above the manufacturing plant of plaintiff located upon said stream, and complained that by reason of said sewage pollution,—

"The water became greatly corrupted and unfit for use in plaintiff's business, 'said water so corrupted, among other things, corroding the plaintiff's boilers and engine and fixtures, causing an adhesion of sediment and other materials to said boilers, and greatly increasing the expense of making

the necessary amount of steam for said works, and greatly increasing the danger of explosion in said boilers, and causing thereby frequent breakages in the engine, fixtures and works, and deterioration thereof, and causing great expense in the repair thereof and in the interruption to the running of the works, thereby causing great injury to all of the plaintiff's establishment.' "

The Court in discussing the question, at pages 219 and 220, say:

"The right, of which the plaintiff alleges a violation, is not that of acquired property in possession. It is not an absolute right, but a natural one, qualified and limited, like all natural rights, by the exercise of like rights in others. It is incident merely to his ownership of land through which the stream has its course. As such owner he has the right to enjoy the continued flow of the stream, to use its force, and to make limited and temporary appropriation of its waters. These rights are held in common with all others having lands bordering upon the same stream; but his enjoyment must necessarily be according to his opportunity, prior to those below him, subsequent to those above. It follows that all such rights are liable to be modified and abridged in the enjoyment, by the exercise by others of their own rights; and, so far as they are thus abridged, the loss is *damnum absque injuria*. The only limit that can be set to this abridgment through the exercise by others of their natural rights, is in the standard or measure of reasonable use. *Gould* v. *Boston Duck Co.*, 13 Gray, 442; *Haskins* v. *Haskins*, 9 Gray, 390; *Tourtellott* v. *Phelps*, 4 Gray, 370-376; *Thurber* v. *Martin*, 2 Gray, 394; *Pitts* v. *Lancaster Mills Co.*, 13 Met., 156; *Wadsworth* v. *Tillotson*, 15 Conn., 366; *Springfield* v. *Harris*, 4 Allen, 494.

"So the natural right of the plaintiff to have the water descend to him in its pure state, fit to be used for the various

purposes to which he may have occasion to apply it, must yield to the equal right in those who happen to be above him. Their use of the stream for mill purposes, for irrigation, watering cattle, and the manifold purposes for which they may lawfully use it, will tend to render the water more or less impure. Cultivating and fertilizing the lands bordering on the stream, and in which are its sources, their occupation by farm houses and other erections, will unavoidably cause impurities to be carried into the stream. As the lands are subdivided and their occupation and use become multifarious, these causes will be rendered more operative, and their effects more perceptible. The water may thus be rendered unfit for many uses for which it had before been suitable; but so far as that condition results only from reasonable use of the stream in accordance with common right, the lower riparian proprietor has no remedy.

"When the population becomes dense, and towns and villages gather along its banks, the stream naturally and necessarily suffers still greater deterioration. Roads and streets crossing it, or running by its side, with their gutters and sluices discharging into it their surface water collected from over large spaces, and carrying with it in suspension the loose and light matter that is thus swept off, are abundant sources of impurity, against which the law affords no redress by action. *Flagg* v. *Worcester*, 13 Gray, 601; *Barry* v. *Lowell*, 8 Allen, 127; *Turner* v. *Portmouth*, 13 Allen, 291."

The same doctrine is announced by the Supreme Court of New York in the case of *Strobel* v. *Kerr Salt Company*, 164 N. Y., 303. We will quote from pages 320 and 321:

"There is nothing about the case now before us to take it out of the general rules governing the rights of riparian owners. These rules are well established in this State, and, so far as material to the case before us, are, in the absence of modification by grant or prescription, as follows: A ripa-

rian owner is entitled to a reasonable use of the water flowing by his premises in a natural stream, as an incident to his ownership of the soil, and to have it transmitted to him without sensible alteration in quality or unreasonable diminution in quantity. While he does not own the running water, he has the right to a reasonable use of it as it passes by his land. As all other owners upon the same stream have the same right, the right of no one is absolute, but is qualified by the right of the others to have the stream substantially preserved in its natural size, flow and purity, and to protection against material diversion or pollution. This is the common right of all, which must not be interfered with by any. The use by each must, therefore, be consistent with the rights of the others, and the maxim of *sic utere tuo* obesrved by all. The rule of the ancient common law is still in force; *aqua currit et debet currere, ut currere solebat*. Consumption by wandering cattle, temporary detention by dams in order to run machinery, irrigation when not out of proportion to the size of the stream, and some other familiar uses, although in fact a diversion of the water involving some loss, are not regarded as an unlawful diversion, but are allowed as a necessary incident to the use in order to effect the highest average benefit to all riparian owners. As the enjoyment of each must be according to his opportunity and the upper owner has the first chance, the lower owners must submit to such loss as is caused by reasonable use. Surrounding circumstances, such as the size and velocity of the stream, the usage of the country, the extent of the injury, convenience in doing business and the indispensible public necessity of cities and villages for drainage, are also taken into consideration, so that a use which, under certain circumstances, is held reasonable, under different circumstances would be held unreasonable."

In the case of *Valparaiso* v. *Hagen*, 153 Ind., at pages 340 and 341 and 342, the Supreme Court of that State says:

"It is equally well established that every owner of land, through which a stream of water flows, is entitled to the reasonable use and enjoyment of the stream. His right to do so is not an acquired property right, but a natural right appurtenant to his freehold, and is in common and equal with all others owning land upon the stream. He may dam it and divert it for mechanical purposes and fish ponds if he will return it to its channel before leaving his premises; he may use it for purposes of agriculture: his animals may take water from it at will; he may clear away the forests, plant crops, fertilize his field, feed his animals in lots, and permit the storm water from his fields and feed yards to flow by natural ways into the stream; or he may collect the surface water upon his premises, if all upon the watershed into ditches, covered or uncovered, and clean or unclean, may direct them into the stream, even though such drainage corrupts the waters of the stream and sends them on to the owners of the servient estates less pure than he received them. His enjoyment is according to his position, superior to those below him and inferior to those above him.

"The right to improve and beautify property and to employ all the reasonable methods afforded by the estate and its appurtenances, to protect the health and promote the comfort and happiness of self and family, is inseparably connected with the right to own and control property; and, though its exercise may sometimes injuriously affect others, the law affords no remedy. In acquiring estates and in erecting homes along water courses, notice must be taken of the conformation of the territory, the natural lines or drainage, that farms, cities and villages may gather along its banks, and that the impurities incident to the trades, to agriculture, and population, that fall upon the surface, will find their way into the stream and that the enjoyment of the stream is liable to be modified and abridged if not altogether suspended

in many uses to which it might originally have been fitted by those above in the exercise of their own equal rights.

"A municipality in large sense is a riparian proprietor. Its officers stand for the corporation. They are empowered by the State to provide and enforce sanitary measures for the preservation of the health and welfare of the public. The corporation has the same right to exist as an aggregation, and to enjoy its possessions, as a natural person. It may under the law establish public halls, libraries, and market places; and it may lay out parks and embellish them with flowers and fountains for the comfort and happiness of the corporate body. It may open and improve streets, construct gutters, sluices and waterways, and if storm water carries into these latter the multifarious filth and garbage incident to populated places and bears the same away by natural channels to the general watercourse of the basin, the right of the municipality to permit it will not be doubted, even though the waters of the stream are thereby so polluted as to render them unfit for ordinary uses.

"And wherein have the dwellers below ground of complaint? They have suffered only that which they should have reasonably expected and estimated in acquiring their property. The question is rooted in the natural law of self preservation. And if cities are permitted to adulterate streams by allowing all accumulating surface impurities to flow into them by natural channels, we do not perceive why the underlying principle will not allow them to deepen these natural storm channels and transform them into covered sewers, nor why the right to protect the health and welfare of the public against one class of noxious matter should not be extended to all classes of equal virulence."

Supporting this doctrine we refer the Court to the remaining authorities cited in paragraph I of propositions of law herewith submitted.

II.

The Acts of Congress of 1822 and 1827 duly authorized the State of Illinois to connect by means of a Canal the waters of Lake Michigan with the waters of the Illinois River. Therefore, the connection of the same and the waters thereof, as done, was a lawful act.

In support of the second proposition we quote herewith the Acts of Congress of 1822 and 1827 referred to:

Act of March 30, 1822, 3rd Stat. at Large, p. 659.

"Section 1. The State of Illinois be and is hereby authorized to survey and mark, through the public lands of the United States, the route of the Canal connecting the Illinois River with the southern bend of Lake Michigan; and ninety feet of land on each side of said Canal shall be forever reserved from any sale to be made by the United States, except in cases hereinafter provided for, and the use thereof forever shall be and the same is hereby vested in the said State for a Canal, and for no other purpose whatever—on condition, however, that if the said State does not survey and direct by law said Canal to be opened, and return a complete map thereof to the treasury department, within three years from and after the passing of this act; or if the said Canal be not completed, suitable for navigation, within twelve years thereafter; or if said ground shall ever cease to be occupied by, and used for, a Canal suitable for navigation, the reservation and grant hereby made shall be void and of none effect: Provided always, and it is hereby enacted and declared, that nothing in this act contained, or that shall be done in pursuance thereof, shall be deemed or construed to imply any obligation on the part of the United States to appropriate any money to defray the expenses of surveying or opening said Canal: Provided also, and it is hereby further enacted and declared, that the said Canal, when completed, shall be,

and forever remain, a public highway for the use of the government, of the United States, free from any toll or other charge whatever, for any property of the United States, or persons in their service, passing through the same.

Section 2. Every section of land through which said Canal route may pass, shall be and the same is hereby reserved from future sale, until hereafter specially directed by law; and said state is hereby authorized and permitted, without waste, to use any materials on the public lands adjacent to said Canal, that may be necessary for its construction."

Act of March 2, 1827, 4th Stat. at Large, p. 234.

"Section 1. There be, and hereby is, granted to the State of Illinois, for the purpose of aiding the said State in opening a Canal to unite the waters of the Illinois River with those of Lake Michigan, a quantity of land equal to one-half of five sections in width, on each said of said Canal, and reserving each alternate section to the United States, to be selected by the commissioners of the land office, under the direction of the president of the United States, from one end of the said Canal to the other; and the said lands shall be subject to the disposal of the legislature of the said State, for the purpose aforesaid, and no other: Provided, that the said Canal, when completed, shall be and forever remain a public highway for the use of the government of the United States, free from any toll, or other charge whatever, for any property of the United States, or persons in their service, passing through the same: Provided, that said Canal shall be commenced within five years, and completed in twenty years, or the State shall be bound to pay to the United States the amount of any lands previously sold, and that the title to purchasers under the State shall be valid.

"Section 2. So soon as the route of the said Canal shall be located and agreed on by the said State, it shall be the duty of the governor thereof, or such other person or persons as

may have been or shall hereafter be, authorized to superintend the construction of said Canal, to examine and ascertain the particular sections to which the said State will be entitled, under the provisions of this act, and report the same to the secretary of the treasury of the United States.

"Section 3. The said State, under the authority of the legislature thereof, after the selection shall have been so made, shall have power to sell and convey the whole, or any part of the said land, and to give a title in fee simple thereof, to whomsoever shall purchase the whole or any part thereof."

In the case of *Wisconsin* v. *Duluth*, 96 U. S., at page 387, bearing upon this proposition this court said:

"If, then, Congress in the exercise of a lawful authority, has adopted and is carrying out a system of harbor improvements at Duluth, this Court can have no lawful authority to forbid the work. If that body sees fit to provide a way by which the great commerce of the lakes and the countries west of them, even to Asia, shall be securely accommodated at the harbor of Duluth by this short Canal of three or four hundred feet, can this Court decree that it must forever pursue the old channel, by the natural outlet, over water too shallow for large vessels, unsafe for small ones, and by a longer and much more tedious route?"

This Court has already held in this case "that the bill in this case does not assail the Drainage Canal as an unlawful structure nor aim to prevent its use as a waterway." *Missouri* v. *Illinois, et al.*, 180 U. S., 248.

The City of Chicago as it lawfully might, discharged its sewage into the Chicago River and Lake Michigan prior to the opening of the Canal. The Act of Congress authorizing the uniting of the waters of Lake Michigan with the waters of the Illinois River by the Drainage Canal, necessarily carried with it the sewage of Chicago then and now being discharged into Lake Michigan and the Chicago River. The

uniting of the waters of the Illinois River with the waters of Lake Michigan being a lawful act authorized by Congress, it is in effect the same as though the City of Chicago was on the natural water shed of the Illinois River. That being the case, the sole and only question is, does the sewage from the Sanitary District materially pollute the water supply of St. Louis. Upon this issue the burden of proof is upon the complainant to show by "satisfactory and determinate evidence" such alleged pollution.

III.

In an action of this kind where each party produces the evidence of a reasonable number of reputable experts, equally schooled in the questions of science at issue, and such evidence shows an irreconcilable conflict, the evidence of numerous non-expert witnesses (especially if uncontradicted), who from personal experience by the actual use of the water, testify that, before and after the alleged contamination complained of, they continuously used the water for drinking and other domestic uses, and for the making of steam and other manufacturing purposes, and that since the doing of the acts complained of the water has been improved for such and all other purposes, the evidence of such non-expert witnesses is of more weight than that of such expert evidence, and should control the decision of the case:

The foregoing acts on the part of the City of Chicago and the State of Illinois, through its agency the Sanitary District, being lawful, it is, therefore, elementary that the burden of proof in this case is upon the complainant, the State of Missouri, to sustain by "determinate and satisfactory evidence" the allegations in its bill. As has been observed, the evidence on behalf of the State of Missouri is almost entirely from experts, men of reputation it is true, but this evidence is specifically contradicted by experts equally as eminent who

have testified on behalf of the defendants. This conflict is irreconcilable. Some three hundred non-expert witnesses have testified on behalf of the defense in substance; that they were acquainted with the Illinois River and used its waters prior to the opening of the Drainage Canal; that they have used the same since; that the opening of the Drainage Canal was an improvement rather than a detriment to the waters. This evidence, we respectfully submit, is entitled to more consideration and is more determinate of the question of fact at issue than the evidence of the scientific witnesses. This especially true where there is a conflict in the scientific evidence.

In the case of *Newark Acqueduct Board* v. *City of Passaic*, 18 Atl. Rep., 106; 45 N. J. Eq. Rep., 393, the complainant was a public body charged with the management of the City of Newark's water supply. They purchased for the City of Newark land bordering upon the Passaic River, a tidal stream, and up on the land thus purchased constructed a pumping station, and abandoning all other sources of water supply for several years had taken large quantities of water for domestic uses by the inhabitants of Newark from the Passaic River. The defendant was situated upon the same river, about four miles above complainant's pumping station. It proposed to discharg its main sewer into the water of the river. Complainant alleged that such discharge would materially pollute the water and thereby create a nuisance injurious to it, and filed a bill for injunction to restrain the proposed discharge of sewage. The plans for the proposed construction contemplated sewers which would discharge into the river 60,000 gallons filth from privies, sinks, and factories. Health statistics exhibited that during the past year 20 per cent. of deaths in Passaic were caused by typhois and scarlet fever, diphtheria, cholera infantum, and dysentery, and it is insisted that the foul excreta of patients suffering with those diseases will be carried into the Passaic River through

the proposed sewers, and therefrom germs of those diseases will be pumped to the complainants distributing reservoirs, and be distributed to a large population, endangering its health.

In support of its contentions, each side introduced the affidavits of eminent chemists, engineers, and water inspectors which were conflicting. After setting out the substance thereof, which should be read, the Court, on page 111, say:

"In the case of *Attorney General* v. *Board*, L. R., 18, Eq. 172, in 1874, I find that Sir George Jessell, M. R., dealt with testimony by Dr. Frankland, of the Royal College of Chemistry in England, which was somewhat similar to that which is here given by Prof. Austen. There Dr. Frankland said that no sewage could be admitted into a river without deteriorating the quality of the water. 'The deterioration,' he said, 'for washing and manufacturing purposes, may be, as in this case insignificant or imperceptible; but for drinking and cooking such water becomes dangerous, because, as the river pollution commissioners have shown, the sewage matter is not perceptibly altered in its character by a flow of seven miles and scarcely diminished in quantity. Neither does the failure of chemical analysis to detect any deleterious ingredient indicate that danger is absent, since the nature of the noxious ingredients which propagate small-pox, scarlet fever, typhoid fever, or cholera is unknown. A chemical analysis is therefore powerless to detect these ingredients.' In the case before me Prof. Austen speaks of these ingredients as germs of diseases called 'microbes;' that is, germs so infinitesimal that they derive their name, 'microbes' from the powerful glass by the aid of which it is claimed they may be detected. The theory advanced by Dr. Frankland was contradicted by other experts, and the master of the rolls, because no impurity was detected in the intake at the Workington water works, declared that a nuisance was not proven.

"In *Goldsmith* v. *Commissioners*, L. R., 1, Ch. App., 349, Lord Justice Turner, referring to the testimony of scientific experts in a case of a nuisance, said: 'Speaking with all possible respect to the scientific gentlemen who have given their evidence, and as to whom it is but just to say that they have dealt with the case most ably and most impartially, I think that in cases of this nature much more weight is due to the facts which are proved than to conclusions drawn from scientific investigations. The conclusions to be drawn from scientific investigations are, no doubt, in such cases, of great value, in aid or in explanation of the facts which are proved, but in my judgment, it is upon the facts which are proved, and not upon conclusions, the court ought in these cases mainly to rely. * * * In my view of the case, therefore, the scientific evidence ought to be considered as *secondary* only to the evidence as to the facts.'

"This view of scientific evidence in cases of this kind so commends itself to me that I am constrained to be guided by it in the disposition of the question of fact I am now considering. The application here is to restrain that which it is alleged will create a nuisance not that which in fact creates a nuisance. The injury is prospective, and it is only possible to judge from experience in similar cases, experiment, and the opinion of experts, whether the apprehension is well grounded and free from doubt. Here two important circumstances appear—First, practically all traces of the Patterson sewage, as far as the same could be detected by chemical analysis, had disappeared in the flowing water of the Passaic, four and a half miles from the place at which it was discharged into the river, although in that part of the river there was no flux and reflux of the tide; and second, the sewage of Newark, washed by the tide to the Newark water intake, readily detectable by chemical analysis, has not produced an injury similar to that which was apprehended from this much smaller

quantity of sewage, to be emptied into the river at a much greater distance from the intake. In the light of these circumstances, it may be asked, why, if imperceptible germs of disease, fraught with danger to health and life, continue in water after all traces of the sewage from which they come, so far as they can be detected by the chemist, are lost, have not their dangerous qualities, become manifested in Newark long before this? This experience seems to be a complete negation of the danger theory advanced in support of this application, or is sufficient, at least, to render it doubtful whether the danger apprehended is more than chimerical. I deem it of sufficient weight to justify me in withholding a preliminary injunction."

The foregoing case was affirmed by the Court of Appeals, 20 Atl. Rep., 54, upon the foregoing reasoning.

In *Laughlin* v. *President & Trustees of Lamasco City*, 6th Ind., 223, a bill was filed by the city to enjoin defendants from constructing a wharf, on the ground that it would be a nuisance. The Court says, on page 227:

"The earlier doctrine was that injunctions would be granted against such things as were clearly public nuisances. A trial of the facts at law was then directed, and the final decree moulded according to the verdict. But, from a review of the authorities in 2 Story Eq., it would seem that the courts have latterly exercised this extraordinary power in a very cautious and guarded form. 2 Story Eq., 271, note 1.

"Besides, in the present case, the evidence, which is all mere matter of opinion, is by no means concurrent. The engineers see nothing but disastrous results. Ross, the builder of these wharfs, is of opinion that these disasters are visionary—that they are entitled to little weight—that experience alone can attest what results will flow from the difference in the wharfs. In such cases of conflicting evidence, and the injury to the public doubtful, if not imaginary, the injunc-

tion should not be granted. Story, *supra*, title 'Injunction.' So when the alleged nuisance is merely eventual or contingent, courts will not grant an injunction."

On the question of the comparative weight to be accorded to the experts in this case, and the laymen who testify as to the condition of the stream, see Wood on Nuisances, Vol. 1, p. 732, Secs. 539 and 540, especially 539, and the last paragraph of 540. See, also, the case of *Newark Aqueduct Board v. City of Passaic*, 18 Atl. Rep. (N. J.), 196, from which quotation has been made above, and the last case above cited, 6th Ind., 223.

IV.

"That an injunction to restrain a nuisance will issue only in cases where the fact of nuisance is made out upon determinate and satisfactory evidence; that if the evidence is conflicting and the injury be doubtful, that conflict and doubt will be a ground for withholding an injunction, and that, where interposition by injunction is sought, to restrain that which it is apprehended will create a nuisance of which its complainant may complain, the proofs must show such a state of facts as will manifest the danger to be real and immediate."

In volume 2 of Story's Equity Jurisprudence, Sec., 924, it is said:

"But in all cases of this sort a court of equity will grant the injunction to restrain a public nuisance only in cases where the fact is clearly made out upon determinate evidence. For if the evidence be conflicting and the injury to the public doubtful, that alone will constitute a ground for withholding this extraordinary interposition; and, indeed, the same doctrine is equally applicable to cases of private nuisance."

In Wood on Nuisances, Vol. 1, p. 732, Sec. 539, it is said:

"The injury must be such as is apparent to the eye in its ordinary condition, and must be clearly traceable to the nui-

sance charged. If there is a reasonable doubt as to the cause of the injury the benefit of the doubt will be given to the defendant if his trade is a lawful one and the injury is not the necessary and natural consequence of the act, as in all actions of this nature the burden of proof is upon the plaintiff."

See,

Spelling on Injunction, Vol. 1, pp. 357, 361.
Am. & Eng. Ency. of Law, Vol. 21, page 706.

"In all other cases the complainant must make out a case showing clearly that the act or thing sought to be restrained will become a nuisance; that it will result in substantial injury to him, be a natural or inevitable consequence of the act sought to be restrained; and that the danger is imminent."

In the case of *Columbia Ave. Saving Fund v. Prison Commission of Georgia*, 92 Fed., 801, it is said:

"To entitle the plaintiff to the relief it seeks against the Prison Commission of Georgia, it must demonstrate by a preponderance of evidence that the structures proposed by the State, and the uses for which they are intended, will pollute the stream from which the water supply of Milledgeville is obtained. The burden of proof is upon the plaintiff in this, as in all cases. If the evidence indicates that a polluting stream, or infectious matter, would assuredly be commingled with the waters of Fishing Creek above the intake of the plaintiff's works, in view of the expert testimony and the scientific authorities quoted the plaintiff would have made a *prima facie* demonstration, supporting its right to the injunction. In that event the defendant, the prison commission, would be under the necessity of producing evidence to satisfy the court that no injury would ensue to the plaintiff or to the public from such contamination. In other words, some actual or practically certain invasion of the rights of the riparian proprietor or user of the water must appear before the Court

will be justified in denying to an adjacent land owner the use, otherwise legitimate, of his property. The citations of authority, accumulated by the assiduity of the plaintiff's solicitors, were perhaps not needed to inform the Court that the distinct and continuous pollution of water by a riparian proprietor is a private and may be public nuisance, which equity may enjoin. That nuisance was early defined."

In *District Attorney* v. *Lynn and Boston Railroad*, 16 Gray (82 Mass.), 245, a bill was filed to restrain the defendant from laying a track for a horse railroad within the limits of the town. The Court, after holding that courts of equity have power to enjoin nuisances, say:

"It is therefore a salutary power if exercised with discretion and confined within reasonable limits. These limits are well defined. A court of equity will not interfere by injunction to restrain a public nuisance unless the existence of the nuisance is clearly established upon full and satisfactory evidence. If the proof is conflicting and the injury to the public uncertain or doubtful, the court will withhold its interposition." (Citing several authorities.)

In *Gallagher* v. *Flury*, 57 Atl. Rep. (Md.), 672, the Court quoted approvingly *Mayor* v. *Smyth*, 64 N. H., 380; 10 Atl. Rep., 709, as follows:

"The act sought to be restrained must be one which, if executed, will inevitably bring on the danger threatened. In *King* v. *Hamill* (54 Atl., 625), it is said: 'It must be plainly shown that acts are threatened which, when completed, will certainly constitute or result in a grievous nuisance.'"

In *Powell* v. *Bently & G. Furniture Co.*, 34 W. Va., 804; 12 S. E. Rep., 1085, which was a bill to inhibit the furniture company from running as a nuisance to plaintiff. The Court say:

"But such cases depend in a peculiar degree upon their own facts and surrounding circumstances; so that courts

of equity should proceed with great caution in abating or restraining such factory by injunction, and not enjoin unless the fact of nuisance is made in some way to appear clearly beyond all ground of fair questioning."

In *Dunn* v. *City of Austin*, 11 S. W. Rep. (Texas), 1125, a bill was filed to enjoin the city from enlarging an old cemetery, which it was claimed was an irreparable injury to plaintiff's property by contaminating the atmosphere, poisoning the wells and rendering the premises sickly and dangerous to life. A demurrer was filed to the bill. The Court quoted from *Kingsbury* v. *Flowers*, 65 Ala., 484, as follows:

"Facts and circumstances should have been stated distinctly from which the court could see plainly that if future interments on these grounds are not prevented there would be a diminution of the complainant's enjoyment of his dwelling, and at least probable injury to the health of his family. It is not enough to allege simply that such consequences will result."

The Court also quotes from *Rouse* v. *Martin*, 75 Ala., 514, as follows:

"A very strong case must therefore be made by the bill, and if there is any reasonable doubt as to the probable effect of an alleged nuisance, either on the proof, affidavits, or on the construction of the facts stated in the bill, there will be no interference until the matter is tested by experiment in the actual use of the property. In determining the question of interference the Court will look at the acts which are stated in the bill, giving little or no weight to the mere opinion of the complainant that they will constitute a nuisance unless a conclusion clearly follows by proper inference from these facts."

We respectfully submit that upon a full consideration of the evidence in this case and the application of the well recognized principle of law thereto, the complainant has failed to sustain the allegations of its bill.

ARGUMENT OF THE FACTS.

Counsel for complainant have divided their argument of the facts under 29 different headings. For the convenience of the Court we will reply to each one of the points raised in the order in which they are presented.

As the complainant's argument consists chiefly of the presentation of the testimony that is favorable to it, we will present, in as brief a form as possible the scientific evidence, followed by the lay testimony, showing that the opening of the Drainage Canal has improved the sanitary condition of the Illinois River.

This arrangement, we believe, owing to the voluminous record and the character of the testimony, will be of convenience to the Court.

1.

"WATER BORNE DISEASES."

On page 59 of complainant's argument it is said, "Typhoid fever or bacilli typhosus is a common water borne disease in this country." We agree with this statement. The further statement, however, that typhoid fever "is caused by crude sewerage being discharged into the water supply" and that the above mentioned diseases are as a general thing "caused by inferior water" and "more readily communicated by means of inferior water supplied than in any other way," we submit is not warranted by the evidence. The sewage itself is not the cause of typhoid fever or the other diseases mentioned. Typhoid fever is caused by the typhoid bacillus entering the intestinal canal. Without the typhoid bacillus there can be no typhoid fever. The theory of spontaneous generation does not apply to bacteria. In order that a colony of typhoid bacteria may form, it is absolutely necessary that

such colony grow from other bacteria. In other words, no matter how much pollution or crude sewage there might be in water, no typhoid bacteria would form in such water and the water could not produce typhoid fever, unless typhoid bacteria were placed therein. It is admitted by *all* the expert witnesses that the only manner in which typhoid bacilli enter sewage is through the dejecta or urine of typhoid fever patients. (Whipple's testimony, 2131.)

A "water borne disease" is not a disease that is produced by water, but a disease that is caused by bacilli that can live in water for a time and can, by means of the water, be borne from the intestinal tract of one human being to another, the water simply being the vehicle of transmission.

Disease producing germs are known as pathogenic germs. *(38.) Pathogenic germs do not multiply or increase in water. (Ravold's testimony, 943.) (Whipple's testimony, 2130.) Dr. Ravold states the usual method by which typhoid is conveyed is "by infection by water polluted with the dejecta of typhoid fever patients containing the typhoid fever bacillus." (832.)

This means not simply an "inferior" water or a "polluted" water, or "sewage." It means that the typhoid bacillus must be actually present in the water notwithstanding the fact that there may also be sewage in the water. The important question in this case is whether typhoid bacillus discharged into the sewers of Chicago survive the journey of 357 miles necessary to convey them from Chicago through the Sanitary Canal, Desplaines, Illinois and Mississippi Rivers (the route they would have to travel), and enter the St. Louis intake. Typhoid bacillus that have lost their virulence do not cause typhoid fever. (Ravold, 832.) "The chances are that the bacillus travelling from Chicago to St.

* This reference is to pages of printed record.

Louis would lose its virulence sooner than one that had traveled only a few miles." (Ravold, 866.)

"After all, the question of determining the safety of drinking water from a river or a lake does not depend upon its physical character and the number of bacteria that may be present, but depends upon the number and kind of pathogenic bacteria present in the water." (Zeit, 4460.)

2-3.

CHOLERA—EPIDEMIC OF CHOLERA.

Nothing is said by counsel as to the longevity of the microorganism causing cholera. There is admittedly no danger to be apprehended by St. Louis from an epidemic of Asiatic cholera, if one should take place in Chicago. Such bacteria would not survive the journey to St. Louis. Prof. Zeit, on page 4523 of the record, says "in the water of the River Ganges, and the River Yumma, which is very rich in organic material, the vibrio of Asiatic cholera will die in two to four hours, according to the experiments of Hankin. I have in none of my experiments found any such conditions. The shortest periods of life I have observed were five days in the waters that I have examined." He further says (4654), "Cholera vibrio have been known to die and disappear from waters after hours. It depended entirely upon the organic material, and the other bacteria present, and then it depended again on the water, the purer the water the longer they live." Assuming that the germs could arrive at the intake, this witness states: "We would have to consider again the same conditions which I have mentioned so many times: that is, the germs would have to be swallowed in sufficient *number*, they must not have lost their virulence, and the resistant forces of the body must be reduced because Prof. Pottenkofer swallowed fresh bouillon cultures of the Asiatic cholera vibrio,

repeatedly, to bring the experimental proof that if the re-sistant forces were normal, you could not produce Asiatic cholera." (4568.) He further states that cholera could not be conveyed to citizens of St. Louis from an epidemic in Chicago, because it is impossible to contract the disease by direct infection and, secondly, upon the basis of the absolute destruction of cholera vibrio in the sewage polluted water before it even leaves Lockport. (4568.)

The facts stated under the head of "Epidemic of Cholera" on page 61 of counsel's brief, are a sufficient answer unto themselves. It will be noted that the dejecta of the Jews was deposited directly into the River Elba within a short distance of the water supply— there was no transporting of the cholera vibrio for a great distance. And at this point, we desire to emphasize the fact that a similar state of facts exists as to all the typhoid epidemics referred to by counsel or witnesses for complainant.

4.

"TYPHOID FEVER, HOW CONTRACTED."

As to the methods enumerated in complainant's argument page 62, as to the manner in which typhoid fever may be contracted, we, in the main, agree. The first method set forth by counsel is "1st. By drinking water contaminated with the micro-organism." It will be seen, however, that the number of necessary bacillus is not here stated nor whether they must be virulent or not. The number and virulency of the bacteria is the important question.

Prof. Zeit says: "A few germs do not produce an infection, even if they are virulent or pathogenic germs. That true in all cases, the *number* is just as essential as the *presence* of the germ itself, and as essential as the decreased resistant forces of the organisms, and as essential as the vir

lence of the germ. Those are really the *four* conditions of infection."

The witness further states:

"It is true that in all infectious diseases the number of the germs is very, very essential in producing an infection. We find that of persons who die of other diseases, 90 per cent. have evidences of an infection by tubercle bacilli somewhere in their bodies. I mean healed tubercular foci. The same also holds true of typhoid. The number of typhoid bacilli essential to produce infection are not found in the amount of water usually used by an individual for drinking purposes, be it lake or river water. I do not believe personally that direct infection can take place in such a manner. I think that if all the sewage of Chicago containing the typhoid bacilli from every case of typhoid fever in the city should get into Lake Michigan, that no one could be infected by the water of Lake Michigan directly, because the dilution of the bacilli and of such sewage, would be so great that one would have to swallow thousands of quarts of water to supply the necessary numbers of typhoid bacilli to produce typhoid fever, and that typhoid infections, in view of the fact that typhoid bacilli do not multiply at the low temperature of water, must take place in an indirect manner. To illustrate, the infected water containing we will say, one typhoid bacillus to so many thousands of gallons, would reach some favorable culture medium, like various food products, and in a favorable temperature, like that of a hot summer day, or in the house, in milk, or in oysters or in vegetables, or in various other foods, the few typhoid bacilli present begin to multiply and produce a pure culture in, on or upon these foods, a person taking of such food, will swallow the necessary number of typhoid bacilli, to bring about an infection, and have typhoid fever, because he has swallowed a culture of many millions of typhoid bacilli, whereas, the other idea of the direct infection by drinking the water is il-

logical, when we consider the biology of the typhoid bacillus, and the tremendous dilution that takes place when turning sewage or other pollution into a large body of water, and the fact that the typhoid bacillus does not multiply at the low temperature of lake or river waters." (Prof. Zeit. 4430-1.)

"If pathogenic bacteria are in the water and have not died there yet, they will be distributed and separated more or less by dilution according to different conditions existing for dilution, and then require mostly, for their pathogenic effect, of first meeting with a favorable temperature, and favorable culture media, before they produce an infection." (Prof. Zeit. 4552.)

5.

TYPHOID FEVER EPIDEMICS.

We wish the Court to bear in mind that the distance from Chicago to St. Louis by way of the Sanitary Canal, Desplaines, Illinois and Missippi Rivers is 357 miles.

The first epidemic referred to by counsel is that of St. Louis in 1892. Counsel say on page 64 of argument, "Upon investigation it was found that the sewerage from Harlem Creek entered the Mississippi River *about one thousand feet above the intake* at Bissell Point."

In the Lausen epidemic counsel state on page 66 of argument, "The water carrying the typhoid fever germs was therefore required to pass through the mountain for a distance of *about a mile*, which it did, and so thoroughly contaminated the water of the spring with typhoid fever as to cause the epidemic."

As to the Plymouth, Pa., epidemic counsel say, on the same page, "Upon investigation it is found that this epidemic was caused by germs of the disease being discharged *upon the*

banks of the reservoir, from which the water supply was obtained."

As to the Lawrence epidemic, referred to on page 66 of brief for complainant, Dr. Ravold says, "It seems that discharges from some typhoid fever cases were emptied into Stony Brook above the water supply, *about three or four miles from the intake*." (466.)

The Lowell epidemic was caused by the infection coming from Stony Creek, at a point *three miles above the intake* of the City of Lowell. (Sedgwick's testimony, 2200.)

The Newburyport epidemic resulted in eight deaths. Prof. Sedgwick attributes the cause of same to be the drinking of the waters of the Merrimac River, which were infected by the dejecta from typhoid patients at Lowell, *twenty-five miles* above Newburyport.

The elimination of the typhoid bacilli from the Merrimac River is here remarkably shown. On page 2206 of the record, Prof. Sedgwick testifies that there were above a thousand cases in Lowell. "In Lawrence, just below, there were several hundred cases." In Newburyport, twenty-five miles below Lowell, some seventy cases appeared. (2208.)

This shows that with one thousand cases at Lowell, in a distance of twenty-five miles, the number became reduced to seventy. On that basis how many cases would there have been 357 miles away?

The Windsor, Vt., epidemic "was attributed by the State Board of Vermont to one case of typhoid fever on the water shed above—*not very far above—a mile perhaps.*" (2208.)

As to the Pittsburg water supply referred to on page 68 of counsel's brief, the Court will note that there was no epidemic in Pittsburg, but the witness states that as a result of the careful study of the conditions in Pittsburg, "it resulted in the recommending of the filtration plant for the City of Pitts-

burg for the reason that in my judgment infectious materials might be brought to cities which had no filtration plant from points as distant as Oil City, or even more remote—113 miles or more." (Sedgwick, 2208.)

The New Haven epidemic was caused by the washing of typhoid germs from a house on the water shed *immediately above* the intake of the water works, where there had been a few cases of typhoid fever.

The epidemic at Grand Forks referred to on page 70 of counsel's brief is attributed to the sewage at Crookston which was deposited into the Red Lake River by means of a broken sewer. The person who testified to this epidemic was Mr. Williams, who also originated the idea of the cause of the Detroit epidemic. This witness states that he never made any personal examination of Crookston or Grand Forks, but saw an article in the Engineering News in 1897 or 1898, which was written about the year 1893 or 1894. (Williams, 2518.)

This is another case where this witness investigated an epidemic four or five years after its occurrence, and who admits that his only knowledge in regard to the same was obtained from an article in the Engineering News, and from conversation that he had with a friend of his. A casual reading of the testimony of this witness will show that he had no reliable information or knowledge upon which an opinion could be given. The Court is respectfully referred to pages 2522-3 of the record, where this is shown.

The above epidemics, which are shown by the record to be the ones most referred to in the literature, if it be admitted were caused by typhoid bacilli being transmitted in water were in every instance attributed to typhoid infected dejecta being deposited in the water at a distance of not more than twenty-five miles above the intake of the particular water supply where the epidemic in question took place. The majority of them however, are attributed to typhoid dejecta

ing discharged immediately into the reservoir or very close to it. No comparison can be made between conditions in this case and the above or following alleged epidemics for the reason that Chicago is located 357 miles above the intake of the St. Louis water works.

The Cumberland epidemic was caused by an infection of its own water supply by a case of typhoid fever just above the intake of its own water works. (Sedgwick's testimony, 2763.)

The Washington epidemic is referred to by counsel on page 72 of their argument. The statement of counsel as to the cause of this epidemic is very ingeniously made, and would lead the Court to believe that this epidemic was caused by typhoid bacilli deposited in the Potomac River at Cumberland, and thereafter traveling a distance of 165 miles. An inspection of the record will show that the witness quoted by counsel testified as follows: "It is recognized that the Potomac is a polluted stream, although there are very few sewered towns upon it, but there are these overhanging privies and the like, and it is anything but a good supply." (Sedgwick, 2764.)

"While there were 18 deaths in Cumberland in January, 1890, no marked excess appears in Washington until March. Furthermore while the epidemic in Cumberland ended in May that in Washington was coatinued vigorously during July and even to some extent during August." (Sedgwick, 2762.)

"I should hardly call the excess of typhoid fever in Washington in 1900, an epidemic, although that term might perhaps very well be applied to it. It was rather an extraordinary and unusual excess of typhoid fever and, in my judgment, this excess was and is directly traceable to the great epidemic of typhoid fever occurring shortly before, and during a portion of the same period in the City of Cumberland, Md.,—germs from that epidemic having apparently passed down the river into the water supply of the City of Washington alive and

virulent. Of course there must have been a considerable removal of germs enroute, else the outbreak in Washington would have been far more severe." (2766.)

This witness states that Captain Gaillard, of the U. S. Engineers, estimates that it takes from four to seven days for the water to flow from Cumberland to the Washington intake, while one of the officials of the U. S. Geological Survey estimates the time at from two to four days, which would make an average of about four days. (2762.)

From the foregoing it will be seen that this witness admits that an epidemic of typhoid fever in Cumberland will not result in an epidemic in Washington, 165 miles below, the water passing from Cumberland to Washington on an average of four days. He also admits that "there must have been a considerable removal of germs enroute."

But we submit that the increase in typhoid in Washington was not the result of the epidemic in Cumberland.

In general, in Washington, the water used for the public service "was taken from the river and carried through a sedimentation basin, where it was allowed to sediment to a certain extent; then it was lifted to a distributing reservoir, and from there sent direct to the citizens; but at times the sedimentation basin was not employed and at those times the water was sent directly to the distributing reservoir. *On this one occasion to which I refer as I understand it, both sedimentation basin and distributing reservoir were out of service.*" (2768.)

Considering the fact that as this witness testifies the increase in Washington was not coincident with the epidemic in Cumberland, many deaths occurring in Cumberland in January, and no marked excess appearing in Washington until March, and the epidemic in Cumberland ending in May while that in Washington was continued until some time dur

ing August, and also considering the fact that at the very time of the increase in Washington the water supply was taken directly from the river without the usual precautionary measures of sedimentation basins and distributing reservoirs, they being out of order at that time, it is more logical to conclude that the increase in typhoid fever in Washington was due to other causes than it is to attribute it to the previous epidemic prevailing in Cumberland, 165 miles away. The reasonableness of the latter deduction will be more fully shown when the evidence in this case as to the longevity of typhoid bacilli and the purification of running streams is considered. Prof. Sedgwick says, "So far as I know, no one has studied the epidemic at Cumberland and the consequent increase in typhoid at Washington, other than Dr. Kober and myself." (2769.)

In answer to statement made on page 73 of complainant's argument that, "So clear was this connection regarded by local authorities and by experts that when a case of Asiatic cholera was reported to have appeared in Cumberland, Maryland, in 1894, great uneasiness was felt by the experts in Washington, though fortunately the case proved to be some thing else than Asiatic cholera," we respectfully refer the court to the testimony of Prof. Sedgwick on cross-examination, as follows:—

"The only expert I know of who had any anxiety about Asiatic cholera in Cumberland being transmitted to Washington was Dr. Kinyoun. (2769.)

My information as to his anxiety arises from reading something that he got in print." (2770.)

This witness also stated:

"The Potomac runs through a thickly populated country. There are a number of towns on the Potomac between Washington and Cumberland. There are a number of towns on either of the branches of the Potomac above Cumberland." (2774.)

The Shenandoah River runs into the Potomac below Cumberland and this witness states:

"The Shenandoah Valley drains into the Shenandoah River, and thence into the Potomac. I don't know of any cases of typhoid in this period and prior to it in the valley of that river, but I have no doubt there were some few cases." (2777.)

"Q. Can you tell me why the cases in January, 1890, in Cumberland, didn't show any effect, if they ever had any, in Washington, in February?

"A. I can not." (2777.)

"I have not undertaken to connect closely the typhoid in Washington with the typhoid in Cumberland, *believing that no such close* connection *could be traced to that*, but that only a broad and general connection was discovered."

There is no positive evidence by the witness, as disclosed by the above evidence, only theoretical assumptions and guesses.

See record page 2780, *et seq.*, for evidence showing that this witness has no knowledge of the sewerage system of Cumberland, nor of what portion of the population of Cumberland discharges its sewage into the Potomac River.

"I made no inquiries as to whether any typhoid fever existed between Washington and Cumberland, of any one excepting the health authorities in Washington and Cumberland. I do not know if there was any typhoid fever at Harper's Ferry." (2787.)

"I do not know how many cases of typhoid existed between Cumberland and Washington along the water shed of the Potomac. I did not make any investigation to ascertain the number." (2788.)

Not one of the epidemics referred to by counsel or testified to by the witnesses was claimed to have been caused by

the transmission of typhoid bacteria by means of water for a distance exceeding 57 miles. The epidemic [illegible]k place at Detroit has been accredited by some of the witnesses for complainant to have originated from the dredging of the harbor of Port Huron on Black River, a distance of 57 miles from Detroit. Black River flows into St. Clair River near its head. Port Huron being situated at the confluence of these two rivers. From Port Huron the St. Clair River flows a distance of 35 miles, where it discharges itself into Lake St. Clair. Lake St. Clair is about 24 miles long. The water supply of Detroit is taken practically from this lake or from the Detroit River a few feet below the point where it takes its origin in Lake St. Clair. (2439-40.)

The dredging of the harbor of Port Huron was done in the early months of 1892. The material was loaded on scows and transported out on the St. Clair River where it was dumped into the stream at a point about 57 miles above the intake of the Detroit water works. There was an epidemic of typhoid fever in the City of Detroit during that year.

The witnesses testify that the only knowledge they have of this epidemic is that which was given by the reports of Gardner Stewart Williams. Mr. Williams was a witness for complainant and an examination of his testimony will disclose the fact that there was no adequate foundation on which could be based the presumption that the typhoid fever in Detroit was due to the causes assigned by him.

This epidemic took place in 1892 and no investigation was made by Mr. Williams until the year 1895. We insist that he was not competent to judge as to the causes which led to the increase of typhoid fever in Detroit. At that time he does not claim to have been an expert, or even a sanitary engineer. From 1891 to February, 1893, he was Superintendent of Erection for the Russell Wheel & Foundry Company, a manufacturing concern, doing a general structural

iron business in the City of Detroit. From the year 1889 to 1893 he followed and practiced that branch of civil engineering known as structural engineer, which consists of the drawing of plans and specifications and having charge of the erection of iron structures. (2487.) Mr. Williams was asked:

"Q. When did you investigate the epidemic of typhoid fever which appeared in Detroit in 1892?

A. From 1895 to the present time.

Q. At the time of this epidemic you made no kind of investigation of it?

A. No, sir." (2487.)

"When I commenced this investigation in 1895 as far as I recall I had no knowledge of a case where the infection was attributed to a travel of more than 30 miles in a water supply." (2490.)

"When I commenced the investigation in 1895 as to the cause of typhoid fever in Detroit in 1892, I think it may be considered that it was a new branch of water engineering and supplies to me." (2491.)

Arithmetical calculations were put to the witness in answer to which he testified that the amount of typhoid bacteria reaching Detroit if they all survived the voyage from Port Huron would be about four to a gallon and that only three-hundredths of one per cent. of the water flowing from Lake St. Clair was pumped into the Detroit water works. (2511.)

The most remarkable thing about the investigation of this epidemic is that Mr. Williams did not know of any deaths from typhoid in Port Huron. Because they had been dredging in the harbor of the City of Port Huron, the material deposited in the St. Clair River, and being unable to assign the epidemic to any other cause, he concluded that it must

have been due to this dredging, and this notwithstanding the fact that he had no knowledge of the existence of typhoid fever at Port Huron either in the year 1890 or 1891. The witness testified as follows:

"My recollection is there had been two cases reported in 1891. My impression is there had been none reported in 1890. When I began this investigation I didn't know of any deaths in Port Huron from typhoid fever. I do not know from the records of the existence of typhoid fever in Port Huron prior to November, 1891, with the exception of the two cases which I recollect.

Q. So that absolutely you never did know and do not now know whether there were more than two cases of typhoid fever in Port Huron?

A. I do not. * * * I cannot positively recollect, but my impression is they were cases, not deaths." (2494.)

As to the two typhoid patients referred to, the witness states on page 2513, "I don't know that they died. I don't know whether the discharges from their bodies were cast into the sewers of Port Huron or were destroyed or disinfected."

This shows how meager are the facts on which this witness, three years after the epidemic took place and at a time when he was not an epidemiologist or sanitary engineer and when the business of water engineering and supplies was "new to him," based the assumption that the typhoid fever existing in Detroit was caused by the removal of material from the harbor of Port Huron, the depositing of same in the St. Clair River, and the transmission of the supposed pathogenic germs contained therein down the St. Clair River through Lake St. Clair, a distance of 57 miles, to the Detroit water works.

The witness admits that he came to this conclusion without

any knowledge as to whether there were any typhoid baccilli in the harbor of Port Huron at the time of the dredging.

Assuming, however, that typhoid bacilli were discharged from the sewers of Port Huron into the Black River, this being a very sluggish stream, and settled into the mud or material that was afterwards removed, it has been established by the evidence in this case that such typhoid bacilli under such conditions would live only a very short time and would have lost their virulence entirely by the time the dredging took place. Such bacteria would have been without vitality before starting on their supposed journey from the place in the St. Clair River where the dredge material was deposited to the Detroit water works, a distance of 57 miles.

The fact is, as shown by the evidence, that the increase of typhoid fever at Detroit in 1892 was more likely to have occurred from the contamination of the water supply near the intake on Lake St. Clair and the Detroit River.

Mr. Williams, as to conditions on Lake St. Clair, testified as follows:

"Q. On the flats of Lake St. Clair there are a number of club houses and summer resorts?

A. The flats of Lake St. Clair are the delta of the St. Clair River and there are a number of summer resorts there.

Q. In fact a number of club houses?

A. Yes, sir.

Q. It is quite a place of resort for the people of Detroit and the surrounding country during the seasons when such resorts are used and opened?

A. Yes, sir.

Q. And a large number of people are there daily?

A. Well, it depends upon what you call a large number. If you should compare it to the population of Detroit I should

say it wasn't a very large number, or even if you were to compare it to the population of Port Huron I wouldn't say it was a large number.

Q. There are three or four thousand people there in the summer every day?

A. I question it. I doubt it. I am quite sure it is not ordinarily the case that any such number of people are there.

Q. During the summer seasons aren't the flats of Lake St. Clair, its marshes, frequented by from two to three thousand people daily at the resorts and in the club houses and in the occupation of fishing?

A. That is a larger number than I should estimate were there.

Q. Well, there is a considerable number?

A. There is a considerable number there, yes.

Q. And the considerable number varies from day to day as to the individuals?

A. Yes, sir, usually.

Q. So that there is a considerable number of constantly changing population upon Lake St. Clair during the summer seasons?

A. Yes, or upon the upper portion of Lake St. Clair. That is, upon the delta of the St. Clair River.

Q. And the dejecta of these people goes directly from all those people directly into the water, doesn't it?

A. I think that that is generally the case. *In fact I know of no other disposition of it.*

Q. Now, as you go from Detroit toward Lake Huron you pass through first the Detroit River?

A. Yes, sir, a portion of it.

Q. How far is it from Detroit, or from the intake of the Detroit water works?

A. You mean from Detroit, or from the intake of the Detroit water works?

Q. Well, from the intake of the Detroit water works?

A. Oh, you would be in Lake St. Clair in going a mile above the Detroit water works. In fact, I think in going a half a mile.

Q. You would probably be in Lake St. Clair?

A. Yes, sir.

Q. Then you travel across Lake St. Clair how far going to St. Clair River?

A. Oh, about 24 miles across.

Q. How far would you travel by St. Clair River until you come to Port Huron, the point opposite the mouth of the Black River in the St. Clair River?

A. That is about 30 miles." (Gardner Williams, 2499-50.)

Dr. Hiram R. Mills, witness for complainant testifies:

"There is considerable agricultural population having its natural drainage into St. Clair River. There are quite a number of summer resorts and club houses on Lake St. Clair. It is a great resort, fishing, duck hunting, boating and clubs. Large numbers of people resort there during the hunting and fishing seasons. There are thousands of people there every day, varying with the seasons.

Q. These people might as well have had typhoid fever as anybody else? A. Just as well.

Q. Especially coming from Detroit?

A. Especially if they had been exposed to it.

Q. Detroit has been rather notorious for typhoid fever for many years, has it not?

A. I don't know any particular notoriety in that line.

Q. More than the average?

A. They may have had quite a number of cases, and so on down along the river and at Port Huron.

Q. Down along the St. Clair River they have had typhoid fever? A. Yes, sir.

Q. About as regularly as any place else? A. Yes, sir.

Q. Both above and below Port Huron? A. Yes, sir.

Q. And on both sides? A. Yes, sir." (2707-8.)

"Boats traveled up and down Lake St. Clair in their passage from one river to the other in 1890. If a boat were passing from Lake Huron into Lake Erie it would pass through St. Clair River, Lake St. Clair and the Detroit River." (Williams, 2497.)

"You would be in Lake St. Clair in going a mile above the Detroit water works. In fact, I think in going half a mile. You would travel across Lake St. Clair about 24 miles to get to the St. Clair River and 30 miles by the St. Clair River to Port Huron. The St. Clair River is the outlet of Lake Huron, Lake Michigan, Lake Superior and all their bays and estuaries, on the travel of the water of these three lakes to the sea." (Williams, 2500.)

This evidence shows that boats traveled up and down Lake St. Clair and on the Detroit River directly opposite the intake of the Detroit water works. It is well known that the dejecta from typhoid patients on board boats plying up and down a lake or river is dangerous to the health of citizens of a community taking their water supply from such lakes or rivers.

In fact, to one case of typhoid fever which existed on a United States revenue cutter in the Harbor of Charlevoix, Mr. Williams ascribes the epidemic that took place in that city. (2526.)

Mr. Williams testifies that a considerable number of people visit in and around Lake St. Clair for the purpose of recreation, hunting and fiishing. He also states that the dejecta of these people goes directly into the water. This record shows that there is such a thing as "walking typhoid." That is, a person may be suffering with typhoid fever, but the attack may not be so severe as to incapacitate him from walking or performing any of his usual duties. Still, the dejecta from such a person contains typhoid bacilli, which are as virulent as those found in the dejecta of a person suffering with a violent attack of the disease.

Dr. Hiram Mills, who was practicing medicine in Port Huron during the years 1890-91 states that down along the St. Clair River they have had typhoid fever about as regularly as any place else, both above and below Port Huron and on both sides of the river. He also states that there is considerable of an agricultural population having its natural drainage into the St. Clair River.

Mr. Williams testifies that the City of St. Clair, having a population of 2,500 or 2,800 in 1890 and Marine City, which he thinks is not quite so large and Algonac, which is nothing more than a village, are located on the shores of the St. Clair River or Lake St. Clair between Port Huron and the Detroit water works. He also states that there are a few villages located on the Canadian shore.

We submit that it is more reasonable to suppose that the increased typhoid fever in Detroit in 1892 was caused by the infectious dejecta deposited by residents of the cities and villages above mentioned, persons on board vessels plying up and down the Detroit River and Lake St. Clair and transient pleasure seekers, hunters and fishermen on Lake St. Clair.

Prof. W. P. Mason, Professor of Chemistry in the Rensselaer Polytechnic Institute, Troy N. Y., who has made a

special study of water analysis and sanitary problems as related to water supply, and who is the author of several works on the subject, is of the opinion that the conclusions of Mr. Williams are not warranted by the facts. He says:

"Q. Are you acquainted with the Detroit epidemic?

"A. To the extent that I have had information appertaining thereto given me by Professor Williams who has testified in this case. He gave it to me at the time that he was collecting it. I talked the matter over with him and it seemed to me that there might be some doubt with reference to the connection between typhoid fever in Detroit and the dredging of the Black River." (6938.)

Prof. Jordan says:

"I have read the testimony that has been given in this case regarding the dredging of the Black River at Port Huron and its supposed connection with the outbreak of typhoid fever in Detroit. As an epidemiologist I do not consider the facts established beyond a reasonable doubt for the reason that other sources of infection have not been eliminated; and, moreover, it is my opinion, as a bacteriologist and epidemiologist, that under the conditions as described typhoid bacilli could not travel from the Black River at Port Huron to Detroit in sufficient numbers and in a sufficiently virulent condition so that they would be capable of causing an outbreak of typhoid fever in the latter place." (6319.)

In making a statement of this epidemic counsel on page 69 of their argument state that deposits of infectious material ranging from one to eight feet in depth were removed by dredging, etc.

Frank F. Rogers, a civil engineer called by complainant, testified that, "the appropriations for the dredging were secured through the influence of local congressmen for the benefit of shipping facilities along the stream and also on account of

making a winter harbor for vessels. The channel was deepened at that time from the neighborhood of 12 ft. to 16 ft. and to the width of 100 ft. in the central portion of the river." (2743.)

"The Black River, in which the dredging was done, is of a dark color as far up as I know it and I know it nearly to its source. The source is in mucky swamps in the northern part of the Huron Peninsular and above, where it is not polluted with city refuse, etc.; I presume it gets its dark color from those mucky swamps." (2742.)

E. J. Haynes, the inspector, who had in charge the dredging operations and who was called by complainant testified as follows:

"This dredging was for the purpose of making a channel in the Black River. The cutting in some cases would be 4 ft. not over that and the average for the entire distance about 2 ft. The river bed proper was blue clay and some sediment and very little sand. There would not be over one-third of the dredged material taken out that would be clay. The rest of the dredging would be mixed entirely with a black muck or it is a wash from the marshes up above and probably one-sixth of the entire remaining material would be sand. The Black River drains and has its origin in some marshes and swamps and this sediment which was in its bottom is partly the wash from those swamps and marshes." (2749-50.)

6.

"BACILLI COLI COMMUNIS."

This subject is treated by complainants, on p. 74 of their argument.

"As to the swallowing of coli bacilli, this is in my opinion not pathogenic. In fact, it has been advocated recently for the

cure of chronic constipation to drink pure cultures of coli bacilli." (Prof. Zeit, 4533.)

All witnesses, except a few of complainant's agree that this bacteria is nonpathogenic, and is found in the alimentary canal of all human beings, and animals and therefore the finding of same in a running stream is an indication that the stream has undergone at some time in the past fecal pollution.

The bacilli coli communis is found most commonly in the intestines of man and certain animals, for example, the cow, horse, pig and I think birds and speaking generally, in warm blooded animals. (Prof. Whipple, 2076.)

Prof. Long says:

"The bacillus coli communis, or the colon bacillus is, as its name implies, a bacterium inhabiting in large numbers that portion of the alimentary tract known as the colon. It is the bacillus commonly found in this situation. It is found in the intestinal discharges not only from man, but from many other of the highest animals; it is found also in waters and soils contaminated with animal excreta." (5995.)

Prof. Jordan says:

"Its longevity under adverse conditions, is greater than that of the typhoid bacillus. This fact and the ease with which it is isolated and identified, combine to render it a particularly significant organism from a sanitary point of view. Owing to the fact that bacillus coli communis leaves the human body in large numbers in feces, it is one of the prevailing forms in fresh sewage. For this reason the presence and relative abundance of bacillus coli communis in water is regarded as one of the most delicate, precise and altogether significant indications of recent sewage pollution." (6000.)

"So far as I have been able to discover, it is at the present time the prevailing opinion among those bacteriologists who deal with sanitary water analysis that the test for the colon bacillus properly applied and interpreted, furnishes one

of the most satisfactory clews to the sanitary condition of a water."

"In this connection it should be emphasized that it is not so much the presence or absence of bacillus coli communis in a large quantity of water that is significant as it is the relative abundance of this micro organism." (6001.)

Witness refers to a statement of Dr. William G. Savage bacteriologist to the Cardiff County Public Health Laboratory, published in an article by Dr. Savage entitled "The significance of the bacillus coli in drinking water" as follows: "It is not so much the presence of coli bacillus which is of possible value, but the number present. The consideration of the problem is essentially quantitative, and the number of bacillus coli in a standard amount of water must be considered. This view is insisted upon by the many English bacteriologists and there can be no doubt of its vital importance." (6202.)

Witness further states: "In further support of the view already expressed as to the significance of bacillus coli in water supplies, I may cite a report of a committee of the American Public Health Association presented at the Washington meeting of this association October 26th to 30th, 1903. This report of the committee on the significance of bacillus coli in water supplies was presented by the Chairman, Prof. S. C. Prescott, Assistant Professor of Biology at the Massachusetts Institute of Technology. The abstract is in part as follows:

"To present a statement of the opinion of the committee individually and as a whole, as probably representing the generally accepted views of sanitary bacteriologists as to the significance of B. coli in water, the following questions were sent to each member; the answers appended, except as otherwise stated, were practically as given below:

1. In view of the fact that numerous investigators have found B. coli in nature where it could not be directly traced to sewage or fecal pollution, do you believe that the colon test

water is as safe an index of pollution as it was formerly regarded to be? Yes, sir.

2. Are you of the opinion that the number of colon bacilli rather than their presence, should be used as a criterion of recent sewage pollution? Yes.

3. To pronounce a water sewage polluted, would you require as evidence that B. coli was present in a majority of one cubic centimeter samples? Yes, in general."

"These opinions or the opinions expressed by these writers coincide with my own experience based on a considerable number of examinations for the presence of bacillus coli communis. It is my judgment that the relative abundance rather than simple presence of this organism should be considered in sanitary water analysis.

"I may add furthermore, that my own opinion as to the significance of the abundance of bacillus coli communis in the waters of a flowing stream, has been greatly strengthened by some recently published investigations in a report on water purification investigation, and on plans proposed for sewerage and water works systems published by the sewerage and water board of New Orleans, Louisiana, 1903.

"The work included in this report has been largely carried out under the supervision of Mr. G. W. Fuller, of New York, who I understand has already testified as a witness in this case." (6003.)

Prof. Whipple, witness for complainant states:

"I hold that if this organism is constantly present, or is very often present in a water, and if this organism is present in such numbers that we can readily determine its presence by analyzing one cubic centimeter or less of the water, it is probable that this is an indication of contamination by fecal matter." (2075.)

Prof. Ravold, complainant's witness states:

"Q. What do you call the bacteria that is found in the water and that is found in the water fed by sewage, and is found in the stomach of animals, including man—or rather in the intestinal canal?

A. The one that has been looked upon as the index of fecal pollution. That one is called bacillus coli communis." (25.)

Prof. Theo. Smith, says:

"In view of the fact that our methods are still unsatisfactory in the isolation of the typhoid bacillus, at least not practicable on a large scale, the colon bacillus affords us the best indication of the possible presence of the typhoid bacillus. (7289.)

"In considering the sanitary condition of a water I have taken it for granted that the most important indication would be the presence of fecal matter because the typhoid bacillus, the bacillus of dysentery, the bacillus of Asiatic cholera and the bacteria of all various diarrhoeal diseases, are contained in relatively large numbers in the feces, in the discharges during, and perhaps some time after these diseases, and hence any test that would indicate the relative number of fecal bacteria would bring us as near to the exact determination of the sanitary condition of the water as we could get. In the study of the fecal bacteria there is one group of bacteria which is present not only in the human feces in large numbers but also in the feces of domestic animals, of the warm blooded animals, and this group of bacilli is very closely related to and probably a progenitor of the typhoid bacillus and any means of revealing the relative numbers of this particular bacillus, the bacillus coli communis and its various varieties, I infer would enable us to judge as accurately as we can without being able to actually isolate the typhoid bacillus itself. It would enable us to judge as accurately as possible of the sanitary quality of the water with reference to fecal pollution." (7288.)

As to the comparisons made by counsel on page 75 of brief as to the average number of times coli was found in the Illinois, Missouri and Mississippi Rivers, we respectfully suggest that the number of colon bacillus found in the Drainage Canal or in the upper stretches of the Illinois River should not be compared with the number found in the Missouri or Mississippi River for the reason that a purification of such waters takes place before reaching Grafton and mixing with the Mississippi River water. The following table, taken from the testimony of Dr. Ravold at the pages of the record indicated, shows, however, that the Missouri River water is much more polluted than the Mississippi and the Illinois is much better than the Mississippi or Missouri—this from the figures of Dr. Ravold, complainant's witness, and are the figures quoted by counsel on page 75. Following is table of averages:

	Oct. 1901	Nov. 1901	General average	Page of record.
Ills. River	53.6	29.17	41.36	245
Miss. River	33.33	62.50	47	249
Miss. River (Alton)	100.00	77.	88.6	275
Mo. River	92.6	80.	86.2	275

This shows the relative purity of the three rivers as indicated by the average number of times colon bacilli were found to be as follows:

Illinois River at Grafton	41.3
Mississippi River at "	47.
Miss. River at Alton	88.6
Mo. River at Ft. Bellefontaine	86.2

Showing that according to the evidence introduced by complainants the Illinois River at Grafton was purer from the standpoint of colon determination than either the Mississippi River at Alton or Grafton, or the Missouri River at its mouth. This is not by a small margin, but the Mississippi and Mis-

souri Rivers as above seen were found to contain colon bacillus more than twice as many times as was the Illinois. Yet this is the very testimony that is quoted by counsel to sustain their contention on page 75 of the brief. But it will be noted that at the bottom of the page the mere statement is made "There is much less coli in the waters of the Missouri than in that of the Mississippi and the Illinois Rivers, as shown by the testimony of Dr. Ravold, printed record, Vol. 1, pages 252-259 inc." Upon turning to the record we find the statements of witness which are incorporated in the above table and respectfully ask the Court to examine the record at the pages indicated, which will show that the record does not sustain counsel's statement.

Counsel state, at p. 75 of argument that "At Grafton, at the mouth of the Illinois River, during the month of October and November, 1901, it was found in 53.6 per cent. of the samples examined and during the same month it was found in but 47 per cent. of the samples examined from the Mississippi River above Grafton and above the mouth of the Illinois." Upon turning to page 245 of the record we discover that counsel has taken by mistake, the first line on the page as indicating the result of the examination for colon bacilli at Grafton. This answer was a mistake of the witness and had counsel gone further down the page the error would have been discovered. The question asked on page 244 of the record is as follows:

"Do you know the percentage of colon bacillus that was found in the samples for *October*, 1901?"

The answer starting at the top of page 245 is as follows:

"A. Yes, sir, October, 1901, 53.6 per cent. for the *two months!*"

Q. For November of the same year?

Mr. Hamlin. The entire time, that is?

A. Yes, 53.6 per cent.

Mr. Hamlin: From October 1st?

A. From October 4th to November 27th. For October, 1901, the coli was found in 53.6 of the cases.

Mr. Jeffries: And for November?

A. For November, 29.17 per cent.

Q. Now, then, *state the average for the two months?*

A. *An average of* 45 *per cent.*"

It will be seen however that 45 is not an average of 53.6 and 29.17—the witness having made an error in the calculation, the proper average being 41.36.

The Court will therefore see that the table compiled above shows the correct testimony of this witness. This table shows 41.36 as the general average for the Illinois River above Grafton. The Mississippi River below its confluence with the Illinois (at Alton) shows a general average of 88.6. (275.) This shows conclusively that the colon bacillus was found in the Mississippi River below the mouth of the Illinois, twice as many times as it was found in the Illinois River above its confluence with the Mississippi. It also shows that the same condition exists so far as the Missouri River is concerned. This shows that counsel's statement that "There is much less coli in the waters of the Missouri River than in that of the Mississippi and the Illinois Rivers" is not supported by the references made by counsel to the testimony of Dr. Ravold, but that such evidence shows exactly the contrary.

Counsel also devote a large part of page 75 to the enumeration of the average number of times this bacillus was found in the water of the Drainage Canal, Illinois River at Peoria, etc. We respectfully ask the Court to compare the average number of times found in the Mississippi, to-wit, 88.6 and in the Missouri River, to-wit, 86.2, with the figures quoted by

counsel. This shows that it was found more times in the Missouri River and Mississippi River than it was found at Joliet or at Peoria.

The evidence of Prof. E. O. Jordan for defendants shows the following results—the table being made from the testimony of witness on the pages of the record named and the figures shown being the percentage of the number of times colon bacillus was found in the samples referred to.

				Page of record.
cc. of water	.001	.01	1.	
Mo. River	19	50	79	6108
Miss. River	5	24	38	6106
Ill. River	7	5	30	6104

Taking the last determination shown which is from samples containing one cubic centimeter of water and therefore more easily found therein we find that the colon bacillus was present in the percentage indicated opposite the river examined as follows:

Missouri River at Bellefontaine	79 per cent.
Mississippi River at Grafton	38 per cent.
Illinois River at Grafton	30 per cent.

Again showing that the Illinois River so far as the colon determination is concerned is much purer than either the Mississippi or Missouri, in fact the colon bacillus having been found in over double the number of samples examined from the Missouri River than were found in the Illinois River.

7.

BACTERIAL CONTENTS OF ILLINOIS, MISSISSIPPI AND MISSOURI RIVERS COMPARED, SHOWING THAT THE LAKE MICHIGAN WATER AND THE SEWAGE OF CHICAGO, IF ANYTHING, HAS A GOOD EFFECT UPON THE WATERS OF THE ILLINOIS RIVER AND OF THE MISSISSIPPI RIVER BELOW THE MOUTH OF THE ILLINOIS RIVER FROM A BACTERIOLOGICAL STANDPOINT.

The argument of complainant under this head beginning with page 76 is ingenious in that it gives to the Court only that part of the testimony which might be construed as favorable to complainant.

A list of places at which samples were taken during what is denominated as the first period of the investigation covers a large portion of the argument. This would lead the Court to believe that many samples were taken by complainant at the places indicated covering an extensive period of time. An examination of the record pages 83-4-5 will disclose that these samples were taken only from August 10, 1899, to September 25th of the same year, which was before the opening of the Drainage Canal and that there were no samples taken by complainant between September 25, 1899, and January 23, 1900. Dr. Ravold, who had charge of the bacteriological investigations on behalf of complainant testified as to the time and place at which samples were taken prior to the opening of the Canal as follows:

"Q. Mr. Hamlin: Now, then, how many samples did you take in the Mississippi River above Grafton in 1899?

A. We took two samples, September 6th and 9th. I collected those myself, Mississippi River four miles above Grafton, September 6th, one sample. Mississippi River six miles

above Grafton, on September 6th, four samples. Now, then, there were collected, Mississippi River one mile above Grafton (845) September 21st; Mississippi River four and one-half miles above Grafton, September 21st, one sample.

Q. Is that all?

A. THAT IS ALL.

Q. How many samples did you take in 1899 on the Illinois River above Grafton, that is immediately above Grafton or at the point where you took them?

A. Illinois River just above Grafton, sample was taken September 9th, Illinois River, one and one-half miles above Grafton. September 21st, one sample Illinois River three miles above Grafton, Wheeler's Ferry. September 6th.

Q. Is that September 6th?

A. The first one was September 26th, Wheeler's Ferry, and September 21st Illinois River five miles above Grafton, Brick House Club September 6th, one sample, September 21st one sample Illinois River seven miles above Grafton.

Q. Is that all? A. That is all, sir.

Q. You got all the samples you took, that you have testified about, in the Illinois River above Grafton in 1899?

A. Yes.

Q. Now, where next did you take samples, in the Illinois River going up stream in 1899? A. The Illinois?

Q. Yes?

A. This seven miles above Grafton, six miles I mean, that is the only sample.

Q. That you have?

A. I find no other record of samples having been taken on these harbor boat trips. (846.)

* * * * *

Q. From the samples that you took in the Illinois River in 1899, are you prepared to state what was the condition of these waters during that year, or any considerable portion of the year?

A. On none other than the time I took the samples.

Q. Would you, as a bacteriologist, state in your judgment as such, that that would be a fair test of the conditions of the water in the Illinois River above Grafton for the year 1899? A. I would not.

Q. Do you know how much sewage was carried into the Illinois River from Chicago in the year 1899?

A. I do not.

Q. Do you know whether or not there was practically the same kind of sewage carried into the waters of the Illinois River from Chicago in 1899 as there is now? A. I do not.

Q. Do you know whether or not there was practically the same kind of sewage carried into the waters of the Illinois River from Chicago in 1899 as there is now? A. I do not.

Q. You have no information on that subject?

A. No, sir." (847.)

Mr. Whipple, witness for complainant, testified as follows:

"Q. In order to determine the general character of a water by microscopical examination, the samples taken and examined ought to be at different times and quite numerous, ought they not?

A. The more frequently the samples are taken, and the more samples that are taken, the more reliable would be our knowledge in regard to the character of the miscroscopic organisms present.

Q. They ought also to be taken at different seasons of the year, ought they not?

A. They ought if you desired to know the character of the water at different seasons of the year.

Q. To know the general character of the water for an entire, year, samples should be taken frequently at different seasons of the year, should they not?

A. If you wanted to know the character of the microscopic organisms in the water for the entire year and the changes which might take place in the number of microscopic organisms present at different seasons, the samples should be taken at different times of the year, and the more frequently these samples were taken the better would be our genral knowledge—the more reliable would be our knowledge in regard to the general character of the water with respect to miscroscopic organisms.

Q. Take one set of samples in a cross-section of the Illinois River and examine them miscroscopically, you wouldn't learn anything except as to the condition of the river at that time?

A. We would learn the condition of the water at the point where the samples were collected at that time.

Q. And that determination would not apply to the condition of the river a month previous, or a month subsequent to those samples? A. It might not.

Q. So that as to the condition of any of the water of any running stream, one set of samples taken at a selected time would give no reliable information?

A. That would give reliable information as to the character of the water of that stream at that time.

Q. And at the very point where the samples were taken

A. At the point where the sample was taken.

Q. And at no other time, or at no other point?

A. No, sir; so far as those samples alone, were concerned

and in the absence of anyone from which we know that those waters remained constant in character through a period of time." (2097-8.)

Mr. Jeffries, of counsel for complainant, agrees with above witnesses for complainant, for on page 4407 of the record he made the following objection:

"Mr. Jeffries: I object to the witness reading the table for the reason that he has stated that he only received seven samples at this place, while he received a larger number at other places, and that by reason thereof, no comparison can be drawn from the bacteriological condition of the water in the respective places. In other words the results so obtained from the samples are not competent." (4407.)

Also see page 4402 of record as follows:

"Mr. Jeffries: I object to the question for the reason that the witness has not stated that a sufficient number of examinations were made to enable anyone to determine the quality of the water at that place, or the particular bacteriological properties of that water with reference to the sanitary condition or unsanitary condition of that water."

Also see record 4399 as follows:

"Mr. Jeffries: Now I move to strike out all that the witness has said with reference to the bottles received from Professor Long, for the reason that bottles so received by this witness as shown by the testimony in evidence was a limited number and not such a number as would justify any conclusions as to the sanitary condition of the water in the Illinois River, and for the further reason that sanitarians are unable to derive any value from the results of a limited number of analyses of any water, and especially water flowing in a running stream, and for the further reason that the evidence shows that the samples so collected were not so taken as to cover storm periods, cold weather periods and all the variations of the river, and the water therein, and for the further

reason that the evidence does not show that the samples were so taken as to obtain a correct bacteriological examination of the water in the Illinois River at flood times, commencing at the source of the flood, or the entrance of the flood into the Illinois River and following it to its mouth, so that any analyses made by this witness of the water of the Illinois River would be incompetent, irrelevant and immaterial and of no probative force."

The fact that only a few samples were examined by witnesses for complainant prior to opening of canal, applies with equal force to the comparisons of chemical data, as they only examined chemically such samples of water as were examined bacterially. The important question in this case is whether the opening of the canal has caused a deterioration in the water of the Illinois River at its mouth. Witnesses for complainant, not having sufficient data to make comparisons of conditions before and after, their evidence is therefore of no weight. On the other hand, witnesses for defendant have taken and examined samples bacterially and chemically from the year 1886 to the time of giving their testimony.

On page 79 of counsel's brief reference is made to the average number of bacteria found in the Illinois and Mississippi Rivers prior to the opening of the Canal. Only two samples were taken at Wheeler's Ferry on the Illinois River. The same number was also taken five miles above the mouth of the Illinois River on the Illinois. On the Mississippi River at Grafton above the mouth of the Illinois, only one sample was taken. It will therefore be seen that the question of averages has very little significance when applied to the samples taken during the so-called first period.

On page 79 of the argument counsel state the number of bacteria that were found in the Illinois River, Mississippi River and Missouri River during the so-called first period. The Court's attention is then called by counsel, beginning at

the bottom of page 79, to the increased number of bacteria found in the Illinois River at Grafton after the opening of the Canal. No reference is made, however, by counsel to the number of bacteria found in the Mississippi or Missouri Rivers after the opening of the Canal. No reliance can be placed upon determinations made by complainants during the year 1899. Furthermore, the same increase had taken place in the Missouri and Mississippi Rivers during the investigation which began on January 23, 1900, as is shown by counsel in the argument to have occurred in the Illinois River. Let us take for instance the Mississippi River six miles above Grafton. This is at a point above the confluence of the Illinois River with the Mississippi and would not, therefore, be affected by the discharge of sewage into the Drainage Canal. Still we find that at this point, while only 276 bacteria per cubic centimeter were found on September 6, 1899, the first sample taken at the same place during the period beginning January 23, 1900, showed 17,000 bacteria per cubic centimeter; January 24th, 30,500; January 25th, 38,300; January 26th, 54,300, etc. In fact, the number fluctuates from the amount first given to 681,800 found in the sample found March 21, 1900. (See p. 135.)

The same conditions apply to the Missouri river.

Counsel state on page 79, that the Missouri at its mouth, during the investigation of 1899, contained 1,070 bacteria per cubic centimeter. A reference to the record at page 161 will disclose the fact that on January 24, 1900, 158,300 bacteria were found at that place; on January 25, 236,000; January 27th, 560,000; and at no time during the months of January, February, March and April, or in fact during the entire period of the investigation, extending from January to October, 1900, did the bacteria ever fall to a point as low as that indicated from the investigation of 1899.

The fact that there was an enormous increase in the num-

ber of bacteria found in the Missouri and Mississippi Rivers after the opening of the Canal shows conclusively that the increase referred to by counsel as having taken place in the Illinois River was due to natural causes and not to the alleged flow of the sewage from Chicago through the Drainage Canal into the Illinois River. Were the increase in the Illinois River due to the sewage from Chicago then no increase should be shown in the Missouri and Mississippi Rivers, which were uninfluenced by the sewage from Chicago.

This so-called increase is not an increase at all. The result is arrived at because comparisons are made of samples taken in the fall of 1899 with samples taken in the Spring of 1900. It is shown by the record that the number of bacteria varies with the seasons—there being more bacteria in the spring during flood periods, etc. Mr. Jeffries' objection is exactly in point when applied to the comparisons made by complainant under this heading. That the increase is due to seasonal variations is shown by the fact that the same increase took place in the Missouri and Mississippi Rivers, although this is not mentioned by counsel. The increase in the Missouri and Mississippi Rivers, however, is greater in proportion than it was in the Illinois River, showing that during the year 1900 the Illinois River was in better sanitary condition than in 1899.

Complainants make a comparison of the number of bacteria found at different places in the Illinois, Missouri, Mississippi Rivers in the so-called investigation of 1899, with the number found at Bear Trap Dam in 1900. Bear Trap Dam is located at Lockport on the Drainage Canal and is about 300 miles away from St. Louis. There is, therefore, no reason why such a comparison should be instituted, as we shall show by the record in another part of this argument, that by the time the water going over the Bear Trap Dam reaches the Mississippi River at Grafton, it compares favorably with the

waters in the tributaries of the Illinois River and is shown to be in better condition than the water of either the Mississippi or Missouri Rivers, and is also shown to have improved in sanitary condition in 1900 when compared with its condition prior to the opening of the Canal.

Comparisons are also made on page 81 of counsel's argument with the average number of bacteria found in the Mississippi River at Hartford, below the confluence of the Mississippi and the Illinois Rivers, being weekly averages from January 30, 1900, to March 27th of the same year—an effort being made to attribute the increase to the influences of the Illinois River. As there was, as above shown, a greater increase in bacteria in the Mississippi River above its confluence with the Illinois River in 1900 than there was in the Illinois River, an increase at Hartford would naturally be found, but such increase instead of being due to the increase in the Illinois, should be attributed to the increase in the Mississippi above its confluence with the Illinois River.

It is true that according to the figures of Dr. Ravold, there were more bacteria per cubic centimeter in the Illinois River after the opening of the Canal than there were before. This ought not to have any weight in the determination of this case, however, for the reason that the same figures disclose that the same state of facts are also applicable to the Missouri and Mississippi Rivers. For instance, the bacterial determinations made in 1899 disclose the fact that in the Mississippi River opposite Grafton, were found 190 bacteria per cubic centimeter. (83.) Immediately after the opening of the Canal, beginning with January 23, 1900, the record shows that during the months of February and March there were all the way from 17,000 to 214,000 bacteria in the Mississippi River above its confluence with the Illinois. Surely the opening of the Canal did not cause this increased number of bacteria to take place in the Mississippi River, for the Illinois River en-

ters the Mississippi below the point at which the samples were taken, from which the results above named were made. The figures quoted by counsel on page 80 to 89, inclusive, of their argument, no doubt show an increased number of bacteria in the Illinois River for the months of February and March immediately following the opening of the Canal. But it will be seen that there are remarkable increases in the number of bacteria found in the Mississippi and Missouri Rivers as well as in the Illinois River. The increase in the Illinois River, however, continued for only a short period, while those in the Mississippi and Missouri continued during the whole investigation. Counsel, however, have followed the determinations in the Illinois River for the months of February and March and make no further comparisons after the week ending March 27, 1900.

We respectfully call the Court's attention to the following table, which is made from Dr. Ravold's testimony, he being a witness for complainant. This table shows the results of the bacteriological examination of the Mississippi River three miles above Grafton, taken from the record beginning at page 135, the Illinois River three miles above Grafton, taken from the record beginning at page 127 and the Missouri River at Fort Bellefontaine, which is a few miles above its confluence with the Mississippi River. The numbers indicate the numbers of bacteria of all kinds found in a cubic centimeter of water from sample taken at the point named, on the day indicated. The plus sign indicates the presence of the bacilli coli communis in the sample of water; the minus sign indicates that the bacillis coli communis was not found. Where there is no sign after the number of bacteria, the witness has not testified that the same was examined for coli.

1900		Illinois River, 3 miles above Grafton. (127)	Mississippi River, 3 miles above Grafton. (135)	Missouri River, at Bellefontaine. (161)
ar.	14	209,300 +	355,400 +	246,900 +
	15	216,800 +	513,000 +	485,900 +
	16	245,600 +	437,000 +	401,500 +
	17	279,800 +	669,600 +	821,500 +
	18	291,000 −	713,000 −	393,800 +
	19	239,800 +	576,900 +	596,600 +
	20	184,000 +	465,700 +	354,000 +
	21	144,600 −	681,800 +	290,000 −
	22	193,400 +	358,700 +	217,000 +
	23	199,000 −	662,000 +	271,500 +
	24	196,000 +	313,000 −	302,200 −
	25	210,800 −	309,500 +	233,000 −
	26	65,000 +	245,300 −	233,000 −
	27	49,500 −	158,000	147,000
	28	88,700 +	221,500	251,500 −
	29	29,500 −	139,000 −	113,000 +
	30	48,800 +	158,700 −	91,300 −
	31	41,560 −	200,000 −	172,500 +
April	1	56,500 −	129,500 +	42,000 +
	2	54,000 +	104,000 +	155,000 −
	3	53,000 +	175,500 −	162,500 −
	4	37,500 +	142,300 −	111,000 −
	5	17,300 −	161,000 −	135,500 −
	6	38,500 −	175,000 −	114,500 −
	7	24,800 +	76,000 −	277,500 +
	8	73,500 +	134,000 −	77,500 −
	9	17,800 +	132,500 −	101,500 +
	10	24,500 +	101,000 +	65,900 −
	11	18,500 +	124,500 +	66,000 −
	12	15,400 −	75,000 −	31,500 +
	13	24,200 −	58,000 +	65,000 +
	14	10,400 +	21,000 +	58,500 −
	15	62,000	63,000 −	87,000 +
	16	18,500 −	44,000 −	87,500
	17	10,500 −	30,000 +	168,500 −
	18	6,200 +	16,800 +	64,500 +
	19	13,000 +	6,500 +	59,500 +
	20	6,000 +	5,100 +	58,300 +
	21	65,000 +	34,300 −	38,000 −
	22	21,300 −	22,000 −	21,500 −
	23	1,500 +	12,600 −	13,900 −
	24	4,800 −	19,700 −	.....
	25	2,900 −	6,400 +	15,400 +
	26	250 −	8,300 +	32,000 −
	27	1,250 −	22,500 +	10,800 +
	28	1,200 −	5,200 +	16,800 −
	29	4,300 −	3,200 +	7,650 +
	30	600 −	1,100 −	1,400 −

1900		Illinois River, 3 miles above Grafton. (127)	Mississippi River, 3 miles above Grafton. (135)	Missouri River, at Bellefontaine. (161)
May	1	600	1,100	3,800
	2	1,700 +	600 +	1,800
	3	750 −	1,000 −	4,200 +
	4	150 −	950 +	4,220 +
	5	600 −	1,200 +	4,100 +
	6	9,100	11,500 +	88,000 +
	7	3,500	3,000 −	40,200
	8	10,600 +	7,900 +	33,100 −
	9	9,700 +	7,300 +	33,100 −
	10	6,820 +	6,400 +	33,100 +
	11	5,200	11,300 −	33,100 +
	12	15,400 −	8,300 −	33,100 −
	13	6,400 −	7,600 +	33,100 −
	14	32,300 +	8,400 +	33,100 +
	15	7,600 +	13,000 +	67,400 +
	16	7,100 −	5,100 +	27,000 +
	17	2,600 −	3,700 +	51,500 −
	18	2,400 +	6,200 −	53,500 −
	19	6,300 −	3,000 −	27,500 −
	20	8,500 −	11,200 +	45,400 −
	21	5,900 +	5,400 −	45,400
	22	6,400 +	4,800	36,000
	23	7,200 +	11,500 +	38,000 +
	24	8,600 −	8,800 +	50,500 −
	25	.....	.....	83,800 −
	26	3,300 +	3,200 +	20,000
	27	.....	+	.....
	28	3,900 +	3,600 +	15,600 +
	29	3,200 +	2,300 −	23,500 +
	30	3,500 +	3,200 −	50,000 +
	31	1,900 +	8,300 −	31,000 +
June	1	34,400 +	5,800 −	78,000 +
	2	16,400 +	7,600 +	44,000 +
	3	7,500 −	4,800 −	34,500 +
	4	9,300 +	11,800 +	28,000 +
	5	13,900 +	4,900 +	19,000 +
	6	6,600 +	4,600 +	41,000 +
	7	6,600 +	8,900 +	41,500 −
	8	7,000 +	3,700 −	71,000 +
	9	6,600 +	6,900 +	51,000 −
	10	8,700 +	2,000	85,000 −
	11	4,000 −	17,600 −	57,000 +
	12	357,000 +	3,300 +	27,500 −
	13	26,600 −	23,100 +	47,000 +
	14	16,900 +	11,400 −	71,000 −
	15	15,800 +	48,300 +	64,000 −
	16	15,800 +	20,300 +	31,000 +
	17	15,800 −	24,000 +	87,000 +

		Illinois River, 3 miles above Grafton. (127)	Mississippi River, 3 miles above Grafton. (135)	Missouri River, at Bellefontaine. (161)			Illinois River, 3 miles above Grafton. (127)	Mississippi River, 3 miles above Grafton. (135)	Missouri River, at Bellefontaine. (161)
1900					1900				
	18	4,000	10,900	62,500 +		5	12,400 +	7,400 +	11,700 +
	19	2,300 +	12,000 +	47,500		6	8,800 +	19,700 +	4,100 +
	20	36,500 +	12,000 +	25,500 −		7	25,600 +	20,600 +	4,100 +
	21	5,800 −	12,000 +	80,000 −		8	13,800 +	16,200 +	13,000 +
	22	57,400 +	2,100 +	78,000 −		9	13,800 +	12,500 +	11,400 +
	23	13,800 +	27,900 +	43,500 +		10	6,400 +	9,200 +	16,100 +
	24	23,200 +	4,700 −	68,500 +		11	4,000 +	1,500 +	22,300 +
	25	79,000 −	13,200 −	76,000 +		12	13,800 +	7,500 +	7,300 +
	26	3,600 +	9,600 +	153,000 +		13	19,300 +	20,100 +	5,600 +
	27	7,400 −	15,300 +	118,500 +		14	3,700 +	12,200 +	11,500 +
	28	5,300 −	9,500 +	112,300 −		15	33,000 +	17,800 +	5,100 +
	29	8,700 −	14,600 +	165,000 +		16	42,600 +	17,800 +	12,400 +
	30	15,500 −	11,800 +	112,300 +		17	5,300 +	35,600 +	1,400 +
July	1	5,100 +	7,800 +	60,000 −		18	1,300 +	29,000 +	6,300 +
	2	6,600 +	33,900 −	65,000 −		19	2,500 +	7,500 +	6,100 +
	3	18,400 +	12,600 +	93,000 +		20	2,800 +	4,900 +	6,700 +
	4	20,600 +	.....	18,900 +		21	8,000 +	27,100 +	6,900 +
	5	1,700 +	12,000 +	240,000 +		22	15,400 +	67,500 +	3,900 +
	6	26,000 +	25,500 +	37,500 +		23	15,400 +	5,600 +	3,400 +
	7	13,100 +	13,900 +	67,000 +		24	2,200 +	37,200 +	7,400 +
	8	17,000 +	5,500 +	43,000 −		25	35,800 +	20,600 +	6,500 +
	9	7,100	19,100 −	47,500 +		26	15,400 +	48,800 +	5,900 +
	10	8,600 +	2,100 −	21,000 +		27	15,400 +	53,800 +	.....
	11	4,000 +	16,900 −	18,500 +		28	15,400 +	134,000 +	7,500 +
	12	22,900 −	5,300 −	28,500		29	1,700 +	10,100 +	9,800 +
	13	34,600 +	7,700 +	15,500 +		30	5,100 +	16,000 +	8,300 +
	14	14,800 −	16,700 −	62,000 +		31	26,400 +	12,800 +	6,300 +
	15	14,600 +	50,400 +	52,000 +	Sept.	1	10,300 +	9,200 +	10,900 +
	16	4,000 +	72,300 +	28,500 +		2	26,400 +	32,200 +	64,100 +
	17	41,000 −	15,800 −	18,500 +		3	17,300 +	11,300 +	9,700 +
	18	11,400 −	6,200 +	26,000 −		4	29,600 +	17,000 +	6,500 +
	19	11,400 +	16,200 +	46,500 +		5	41,500 +	9,800 +	19,800 +
	20	11,400 +	9,200 +	34,400 +		6	15,400 +	17,000 +	16,700 +
	21	3,200 −	2,300 +	11,800 +		7	22,000 +	33,900 +	15,200 +
	22	3,800 +	6,300 −	11,900		8	29,600 +	25,600 +	12,600 +
	23	8,600 +	8,100 −	34,400 +		9	53,000 +	45,600 +	6,300 +
	24	6,300 +	5,200 +	37,400 +		10	16,400 +	4,400 +	9,100 +
	25	4,400 +	2,900 +	10,200 −		11	30,400 +	4,700 +	6,700 +
	26	9,000 +	11,800 +	22,900 −		12	4,900 +	3,600 +	7,700 +
	27	1,300 +	6,700 +	18,300 +		13	2,000 +	5,100 +	5,800 +
	28	38,000 +	11,800 +	19,000 +		14	3,200 +	7,300 +	4,300 +
	29	32,000 +	11,800 +	29,500 +		15	7,300 +	8,000 +	4,100 +
	30	18,200 +	32,600 −	8,700 −		16	1,900 +	16,000 +	4,400 +
	31	8,800 +	28,900 +	.....		17	1,600 +	12,300 +	13,200 +
Aug.	1	8,800 +	28,500 +	14,900 +		18	2,400 +	5,800 +	9,100 +
	2	8,800 +	48,800 +	18,200 +		19	.....	.....	13,400 +
	3	9,100 +	4,600 +	5,800 +		20	22,000 +	6,500 +	.....
	4	4,800 +	7,300 +	4,500 +		21	1,500 +	5,200 +	64,000 +

	Illinois River; 3 miles above Grafton. (127)	Mississippi River, 3 miles above Grafton. (135)	Missouri River, at Bellefontaine. (161)		Illinois River, 3 miles above Grafton. (127)	Mississippi River, 3 miles above Grafton. (135)	Missouri River, at Bellefontaine. (161)
1900				1900			
22	2,900 +	20,800 +	40,000 +	12	.....	.....	.....
23	7,800 +	4,200 +	105,500 +	13	.....	.....	.....
24	3,000 +	77,500 +	69,300 +	14	.....	9,100 +	.....
25	39,200 +	12,500 +	64,200 +	15	.....	2,200 –	.....
26	56,200 +	95,000 +	34,900 +	16	.....	.....	.....
27	1,300 +	3,700 +	48,000 +	17	.....	.....	.....
28	1,100 +	31,200 +	4,700 +	18	.....	.....	.....
29	4,200 +	12,800 +	27,000 +	19	.....	.....	9,000 +
30	5,200 +	9,200 +	26,200 +	20	.....	.....	.....
Oct. 1	7,100 +	26,400 +	16,600 +	21	.....	.....	.....
2	10,000 +	46,600 +	22,600 +	22	.....	.....	.....
3	13,000 +	12,200 +	24,800 +	23	.....	1,800 +	.....
4	22,400 +	11,600 +	30,000 +	24	.....	.....	.....
5	60,600 +	44,000 +	21,600 +	25	.....	.....	29,500 +
6	1,400 +	19,000 +	29,600 +	26	.....	.....	.....
7	1,400 +	2,200 +	22,400 +	27	.....	.....	.....
8	8,400 +	9,400 +	16,800 +	28	.....	.....	.....
9	400 +	4,400 +	26,600 +	29	.....	4,400 +	.....
10	850 +	6,300 +	36,400 +	30	.....	.....	.....
11	.....	.....	.....	31	.....	.....	.....

This table begins where counsel for complainant ceased to make comparisons.

Reading down these columns we find that the Mississippi River and the Missouri River have from two to three times the number of bacteria per cubic centimeter than the Illinois. The Court will find practically the same conditions throughout the entire investigation which was ended on October 31, 1901. On October 10th which was the last day on which samples were taken at the three rivers at the points heretofore indicated, the results were as follows: Illinois River, 850 bacteria per cubic centimeter; Mississippi River, 6,300, and Missouri River, 36,400. We submit that a close examination of the table referred to will disclose that the Missouri and Mississippi Rivers contained a larger number of bacteria than did the Illinois and this condition existed and continued dur-

ing the whole investigation with the exception of the first few months referred to by complainant in their argument. It must be remembered by the Court that this table is made entirely from the figures given by Dr. Ravold who was the principal witness for the complainant, and are not in any way figures offered by witnesses for the defendants. The testimony for defendants will be discussed in another part of the argument.

Following out comparisons made by counsel by weeks, on pages 84 and 85 of their argument, and beginning with the week after the one last referred to by counsel, we have the following results. These figures are taken from page 368 of the record, being the testimony of Dr. Ravold:

Week beginning March 13th:

Illinois River at Grafton, 276,700.
Mississippi River at Grafton, 490,200,
Mississippi River at Alton, 312,300,
Mississippi River at Hartford, 320,500,
Missouri River at Ft. Bellefontaine, 435,500,
Missouri Shore, Chain of Rocks, 484,800,
Illinois Shore, Chain of Rocks, 374,300,
Intake, 484,900.

It will be observed from the foregoing table that the Mississippi River above Grafton contained 213,500 more bacteria than the Illinois River did at its mouth, and the Missouri River at Ft. Bellefontaine contained 158,800 more bacteria than did the Illinois; and the number of bacteria found at the intake were 208,200 more than were found in the Illinois River at its mouth.

We do not desire to weary the Court with a repetition of the above comparisons, but have reproduced below the tables which were read in evidence, beginning with page 386 of the record. These tables speak for themselves and show that during the entire period of examination, the Illinois River had

a less number of bacteria per cubic centimeter than did either the Mississippi or Missouri, leaving out of consideration the first two months that elapsed after the opening of the Drainage Canal:

Week beginning March 20th:
Illinois River at Grafton, 204,300,
Mississippi River at Grafton, 433,700,
Mississippi River at Alton, 156,000,
Mississippi River at Hartford, 227,600,
Missouri River at Ft. Bellefontaine, 271,500,
Missouri Shore, Chain of Rocks, 314,800,
Illinois Shore, Chain of Rocks, 253,800,
Intake, 511,800.

Week beginning March 27th:
Illinois River at Grafton, 158,500,
Mississippi River at Grafton, 142,000,
Mississippi River at Alton, 90,000,
Mississippi River at Hartford, 60,500,
Missouri River at Bellefontaine, 139,000,
Missouri Shore, Chain of Rocks, 70,000,
Illinois Shore, Chain of Rocks, 76,000,
Intake, 118,500,

Week beginning April 3rd:
Illinois River at Grafton, 142,500,
Mississippi River at Grafton, 37,500,
Mississippi River at Alton, 59,500,
Mississippi River at Hartford, 58,000,
Missouri River at Ft. Bellefontaine, 140,000,
Missouri Shore, Chain of Rocks, 76,000,
Illinois Shore, Chain of Rocks, 47,500,
Intake, 118,000.

Week beginning April 10th:
Illinois River at Grafton, 24,000,
Mississippi River at Grafton, 69,000,

Mississippi River at Alton, 23,500,
Mississippi River at Hartford, 34,000,
Missouri River at Ft. Bellefontaine, 66,000,
Missouri Shore, Chain of Rocks, 62,500,
Illinois Shore, Chain of Rocks, 37,000,
Intake, 90,000.

Week beginning April 17th:
Illinois River at Grafton, 9,000,
Mississippi River at Grafton, 18,500,
Mississippi River at Alton, 9,500,
Mississippi River at Hartford, 16,000,
Missouri River at Ft. Bellefontaine, 49,000,
Missouri Shore, Chain of Rocks, 21,000,
Illinois Shore, Chain of Rocks, 14,500,
Intake, 37,000.

Week beginning April 24th:
Illinois River at Grafton, 2,500,
Mississippi River at Grafton, 11,000,
Mississippi River at Alton, 10,000,
Mississippi River at Hartford, 7,500,
Missouri River at Ft. Bellefontaine, 49,000,
Missouri Shore, Chain of Rocks, 11,500,
Illinois Shore, Chain of Rocks, 9,000,
Intake, 12,000.

Week beginning May 1st:
Illinois River at Grafton, 2,500,
Mississippi River at Grafton, 2,000,
Mississippi River at Alton, 7,000,
Mississippi River at Hartford, 11,500,
Missouri River at Ft. Bellefontaine, 16,500,
Missouri Shore, Chain of Rocks, 10,500,
Illinois Shore, Chain of Rocks, 2,500,
Intake, 7,000.

Week beginning May 8th:
Illinois River at Grafton, 12,500,
Mississippi River at Grafton, 7,000,
Mississippi River at Alton, 13,500,
Mississippi River at Hartford, 15,500,
Missouri River at Bellefontaine, 22,000,
Missouri Shore, Chain of Rocks, 46,000,
Illinois Shore, Chain of Rocks, 21,500,
Intake, 23,500.

Week beginning May 15th:
Illinois River, at Grafton, 6,000,
Mississippi River at Grafton, 6,500,
Mississippi River at Alton, 16,000,
Mississippi River at Hartford, 18,000,
Missouri River at Ft. Bellefontaine, 45,500,
Missouri Shore, Chain of Rocks, 43,000,
Illinois Shore, Chain of Rocks, 24,000,
Intake, 13,500.

Week beginning May 22nd:
Illinois River at Grafton, 6,000,
Mississippi River at Grafton, 6,500,
Mississippi River at Alton, 8,000,
Mississippi River at Hartford, 6,000,
Missouri River at Ft. Bellefontaine, 40,500,
Missouri Shore, Chain of Rocks, 29,500,
Illinois Shore, Chain of Rocks, 9,000,
Intake, 4,000.

Week begining May 29th:
Illinois River at Grafton, 9,500,
Mississippi River at Grafton, 5,500,
Mississippi River Alton, 7,000,
Mississippi River at Hartford, 8,000,
Missouri River at Ft. Bellefontaine, 52,000,

Missouri Shore, Chain of Rocks, 25,000,
Illinois Shore, Chain of Rocks, 20,000,
Intake, 17,000.

Week beginning June 5th:
Illinois River at Grafton, 6,500,
Mississippi River at Grafton, 7,000,
Mississippi River at Alton, 12,500,
Mississippi River at Hartford, 6,000,
Missouri River at Ft. Bellefontaine, 55,500,
Missouri Shore, Chain of Rocks, 22,500,
Illinois Shore, Chain of Rocks, 26,000,
Intake, 23,500.

Week beginning June 12th:
Illinois River at Grafton, 16,000,
Mississippi River at Grafton, 20,000,
Mississippi River at Alton, 9,000,
Mississippi River at Hartford, 5,000,
Missouri River at Ft. Bellefontaine, 63,500,
Missouri Shore, Chain of Rocks, 38,500,
Illinois Shore, Chain of Rocks, 21,500,
Intake, 26,500.

Week beginning June 19th:
Illinois River at Grafton, 31,000,
Mississippi River at Grafton, 12,000,
Mississippi River at Alton, 5,500,
Mississippi River at Hartford, 5,000,
Missouri River at Ft. Bellefontaine, 112,500,
Missouri Shore, Chain of Rocks, 38,500,
Illinois Shore, Chain of Rocks, 20,500,
Intake, 17,500.

Week beginning June 26th:
Illinois River at Grafton, 6,500,
Mississippi River at Grafton, 14,500,

Mississippi River at Alton, 6,000,
Mississippi River at Hartford, 4,500,
Missouri River at Ft. Bellefontaine, 105,500,
Missouri Shore, Chain of Rocks, 17,000,
Illinois Shore, Chain of Rocks, 10,500,
Intake, 13,000.

Week beginning July 3rd:
Illinois River at Grafton, Illinois, 17,000,
Mississippi River at Grafton, 15,500,
Mississippi River at Alton, 3,500,
Mississippi River at Hartford, 3,500,
Missouri River at Ft. Bellefontaine, 29,500,
Missouri Shore, Chain of Rocks, 1,000,
Illinois Shore, Chain of Rocks, 10,500,
Intake, 14,000.

Week beginning July 10th:
Illinois River at Grafton, 15,000,
Mississippi River at Grafton, 24,000,
Mississippi River at Alton, 3,500,
Mississippi River at Hartford, 7,000,
Missouri River at Ft. Bellefontaine, 27,500,
Missouri Shore, Chain of Rocks, 20,500,
Illinois Shore, Chain of Rocks, 8,000,
Intake, 19,000.

Week beginning July 17th:
Illinois River at Grafton, 11,500,
Mississippi River at Grafton, 9,000,
Mississippi River at Alton, 18,000,
Mississippi River at Hartford, 4,000,
Missouri River at Ft. Bellefontaine, 21,000,
Missouri Shore, Chain of Rocks, 17,500,
Illinois Shore, Chain of Rocks, 7,500,
Intake, 13,000.

Week beginning July 24th:
Illinois River at Grafton, 18,000,
Mississippi River at Grafton, 12,000,
Mississippi River at Alton, 5,000,
Mississippi River at Hartford, 3,000,
Missouri River at Ft. Bellefontaine, 10,500,
Missouri Shore, Chain of Rocks, 10,000,
Illinois Shore, Chain of Rocks, 4,500,
Intake, 7,000.

Week beginning July 31st:
Illinois River at Grafton, 9,000,
Mississippi River at Grafton, 20,000,
Mississippi River at Alton, 2,500,
Mississippi River at Hartford, 1,500,
Missouri River at Ft. Bellefontaine, 10,500,
Missouri Shore, Chain of Rocks, 6,500,
Illinois Shore, Chain of Rocks, 5,000,
Intake, 4,500.

Week beginning August 7th:
Illinois River at Grafton, 14,000,
Mississippi River at Grafton, 12,500,
Mississippi River at Alton, 1,000,
Mississippi River at Hartford, 1,500,
Missouri River at Ft. Bellefontaine, 7,000,
Missouri Shore, Chain of Rocks, 10,000,
Illinois Shore, Chain of Rocks, 4,500,
Intake, 8,500.

Week beginning August 14th:
Illinois River at Grafton, 12,500,
Mississippi River at Grafton, 18,000,
Mississippi River at Alton, 2,000,
Mississippi River at Hartford, 2,000,
Missouri River at Ft. Bellefontaine, 5,500,
Missouri Shore, Chain of Rocks, 10,000,

Illinois Shore, Chain of Rocks, 5,500,
Intake, 6,500.

Week beginning August 21st:
Illinois River at Grafton, 15,500,
Mississippi River at Grafton, 36,500,
Mississippi River at Alton, 3,000,
Mississippi River at Hartford, 3,500,
Missouri River at Ft. Bellefontaine, 14,000,
Missouri Shore, Chain of Rocks, 10,500,
Illinois Shore, Chain of Rocks, 3,500,
Intake, 14,000.

Week beginning August 28th:
Illinois River at Grafton, 26,500,
Mississippi River at Grafton, 32,000,
Mississippi River at Alton, 7,000,
Mississippi River at Hartford, 3,500,
Missouri River at Ft. Bellefontaine, 12,500,
Missouri Shore, Chain of Rocks, 12,000,
Illinois Shore, Chain of Rocks, 8,500,
Intake, 6,500.

Week beginning September 4th:
Illinois River at Grafton, 29,000,
Mississippi River at Grafton, 17,000,
Mississippi River at Alton, 1,500,
Mississippi River at Hartford, 2,500,
Missouri River at Ft. Bellefontaine, 6,500,
Missouri Shore, Chain of Rocks, 5,500,
Illinois Shore, Chain of Rocks, 2,000,
Intake, 4,500..

Week beginning September 11th:
Illinois River at Grafton, 7,500,
Mississippi River at Grafton, 8,000,
Mississippi River at Alton, 1,000,

Mississippi River at Hartford, 1,000,
Missouri River at Ft. Bellefontaine, 40,500,
Missouri Shore, Chain of Rocks, 24,000,
Illinois Shore, Chain of Rocks, 1,500,
Intake, 30,500.

Week beginning September 18th:
Illinois River at Grafton, 3,000,
Mississippi River at Grafton, 8,568,
Mississippi River at Alton, 2,000,
Mississippi River at Hartford, 2,500,
Missouri River at Ft. Bellefontaine, 36,000,
Missouri Shore, Chain of Rocks, 30,500,
Illinois Shore, Chain of Rocks, 8,000,
Intake, 25,500.

Week beginning September 25th:
Illinois River at Grafton, 3,000,
Mississippi River at Grafton, 14,500,
Mississippi River at Alton, 4,000,
Mississippi River at Hartford, 4,000,
Missouri River at Ft. Bellefontaine, 36,000,
Missouri Shore, Chain of Rocks, 30,000,
Illinois Shore, Chain of Rocks, 13,000,
Intake, 25,500.

Week beginning October 2nd:
Illinois River at Grafton, Ill., 16,500,
Mississippi River at Grafton, 20,500,
Mississippi River at Alton, 2,000,
Mississippi River at Hartford, 2,500,
Missouri River at Ft. Bellefontaine, 24,000,
Missouri Shore, Chain of Rocks, 23,500,
Illinois Shore, Chain of Rocks, 6,000,
Intake, 17,000.

The court's attention is respectfully called to the fact that

the above figures are those given by witness for the complainant.

On page 86 of their argument counsel refer to conditions on January 23rd, and quote Dr. Ravold as stating that there was a general mixture of the Illinois, Mississippi and Missouri River waters at the intake. We submit to the court that an examination of the tables above referred to will disclose the fact that during a majority of the weeks for which these averages are given, the number of bacteria found in the intake greatly exceeded those found in the Illinois River, thus showing that the bacteria at the intake come from the Mississippi and Missouri Rivers and that the Illinois River, instead of polluting the waters at the intake rendered them purer. For instance, 204,300 bacteria were found in the Illinois River during the week beginning March 20th, while 511,800 were found at the intake during the same week; for the week beginning April 10th, 24,000 were found in the Illinois River, and 90,000 at the intake; for the week beginning April 17th, 9,000 were found in the Illinois River and 37,000 at the intake; week beginning April 24th, Illinois River 2,500, intake 12,000; week beginning May 1st, Illinois River 2,500, intake 7,000; week beginning May 8th, Illinois River 12,500 and intake 23,500; May 15th, Illinois River 6,000, intake 13,500; for the week beginning May 22nd, a less number were found at the intake than were found either in the Mississippi, Illinois or Missouri Rivers; May 29th, Illinois River 9,500, intake 17,000; week beginning June 5th, Illinois River 6,500, intake 23,500. One might go through this table to the week ending the examination, beginning October 2nd, and find that the above conditions existed during each week, which clearly indicates that the amount of bacteria found at the intake are contributed to more largely by the Missouri and Mississippi Rivers than they are by the Illinois. Another remarkable fact is that when there are less bacteria in the intake than are found in the Illinois River, as occurs in a few instances,

it will be found that there are also more bacteria in the Missouri and Mississippi Rivers during the same week. For instance, for the week beginning May 22nd, 6,000 bacteria were found in the Illinois River at Grafton and only 4,000 at the intake, but we also find that 6,500 were found in the Mississippi River above Grafton and 40,500 in the Missouri River at the same time. (370.)

Although the number of bacteria may have increased during this period as compared with 1899, before the opening of the canal, in the Illinois River, yet it is shown that during the same time the increase in the number of bacteria in the Mississippi River above the mouth of the Illinois and in the Missouri River was correspondingly much larger. This shows that the increase was from natural causes, such as floods, high waters, etc. During such times the number of bacteria naturally and unavoidably increase, but they are not necessarily pathogenic germs, but on the contrary are harmless.

We have made no reference to the bacterial determinations made by witnesses for the defendants, but have used entirely the testimony and figures of witnesses for complainant in this portion of the argument.

8.

THE BACTERIAL CONDITION OF THE ILLINOIS RIVER HAS NOT GROWN MORE DANGEROUS SINCE THE CANAL WAS OPENED.

Counsel state on page 89 of their argument that there is an increase in the number of bacteria at Averyville, which is located a few miles above Peoria on the Illinois River, and Kampsville and Grafton, below Peoria, since the opening of the Canal, as compared with conditions prior thereto, and refer to page 5967 of the record, where Dr. Jordan, a witness

for defendants, has made this comparison. Dr. Jordan, however, at this point is only making comparisons of the Illinois River from averages for the two periods. It must be taken into consideration by the court that the number of bacteria in a stream varies with the seasons of the year—there being much more in Spring during flood periods than there is in times of low water. This is due to the fact that common harmless bacteria are washed from the water shed into the stream. The examination of 1899 by defendants was made from June to December 30th of that year. This included the dry summer and fall season. The examination of 1900 was conducted from January to June, thus taking in the flood periods during the spring. It is therefore only natural that there should be an increased number of bacteria in 1900, taking an average of the period. The important question, however, is whether this increase in the Illinois River as compared with its tributaries and other streams uninfluenced by the Chicago Drainage Canal is greater or smaller than the increase in those streams. If there was not a corresponding increase in the Illinois River, then the influence of the Drainage Canal on the Illinois River has been to eliminate from it a large number of bacteria and thus make it purer from a bacteriological standpoint. If we turn to page 5958 of the record we will find table "E" introduced as part of the testimony of this same witness Dr. Jordan, which shows the following state of facts: That the average number of bacteria for the year 1899 in the Kankakee River, a tributary of the Illinois, was 5,000, and in the year 1900, after the opening of the canal, 16,100; that the average number found in the Fox River, a tributary of the Illinois, in 1899 was 6,500, and in 1900 20,600; the average number found in the Big Vermillion River at La Salle, another tributary of the Illinois, was 7,970 in 1899, and in 1900, 19,200. It will thus be noted that there was an increase of about three times the number of bacteria in the tributaries of the Illinois River during the 1900 period than

there was during the year 1899. However, the number found in the Illinois River at Grafton in 1899 was 10,210, and in the year 1900, 21,000, which is only an increase of double the amount as compared to the enormous increase in the tributaries, showing that notwithstanding the tributaries of the Illinois had a larger amount of bacteria, comparatively speaking, than the Illinois River did, that by the time the water reached Grafton these bacteria had disappeared to such an extent that the Illinois River only contained double the amount in 1900 as compared with 1899, whereas the tributaries, which are not affected by the Drainage Canal, contained treble the amount. This shows that the opening of the canal had the purifying effect of reducing the number of bacteria per cubic centimeter in the Illinois River, so far as the increase is concerned, one-third less than the amount in its tributaries.

The increased amount of bacteria during the year 1900 is shown to be due to natural conditions, for we find that there was an increase at all points where samples were taken. Counsel, however, fail to make a comparison as to anything but the Illinois River, which is misleading, as comparisons should be made of all the streams in question.

As above seen there was an increase in the tributaries of the Illinois River one-third greater than there was in the Illinois River itself at Grafton.

Upon turning to page 5958 of the record we find that while in 1899 there were only 7,600 bacteria per cubic centimeter in the Mississippi River above the mouth of the Illinois, there were 30,600 during the period of 1900. Thus it is seen that while the Illinois River had twice as many bacteria during the period of 1900 as it did in 1899, the Mississippi River had trebled the number in 1900 that it had in 1899. And while the Illinois River in 1900 only had an average of 21,000 bacteria, we find that the Mississippi River had 30,600, which is nearly one-third more.

A more remarkable increase is shown in the Missouri River. The table on page 5959 of record shows that during the year 1899 the average number of bacteria was 8,170 in the Missouri River before it enters into the Mississippi, while during the year 1900 the number increased to 43,100, being about five times as many in 1900 as there were during the year 1899. These figures also show that the Missouri River in 1900 had twice as many bacteria as did the Illinois.

The above figures show that there was a general increase in the number of bacteria found in the various water under investigation during the year 1900 as compared with the year 1899. This is true of the Illinois River above Grafton, of the Mississippi River above Grafton, and the Missouri River at its mouth. But the comparisons referred to also indicate that while the Illinois River has double the amount of bacteria in 1900 that it had in 1899, the Mississippi River had treble the amount in 1900 that it had in 1899, and the Missouri River had five times the amount in 1900 that it had in 1899.

We also find that while the Illinois River at Grafton for the year 1900 had 21,000 bacteria, the Mississippi River had 30,000, and the Missouri River had 43,000. This shows that during the 1900 period or for six months following the opening of the canal, the Illinois River was much purer than either the Missouri and Mississippi Rivers.

These figures also show that the opening of the Drainage Canal resulted in the purification of the Illinois River, otherwise the same relative increase in bacteria would have taken place in the Illinois River as occurred in its tributaries in the Mississippi or Missouri Rivers. This shows conclusively that the addition of the pure Lake Michigan water to the waters of the Illinois River has purified the Illinois River and decreased the number of bacteria therein.

We submit that the proposition laid down by counsel on

page 90 of their argument is not supported by the references to the testimony made on page 91. The statement is as follows:

"More striking is this (the finding of certain pathogenic bacteria) when you take into consideration the fact that bacteriologists have been using every possible means to discover some way by which pathogenic bacteria might be readily determined in the water. So far as typhoid fever germs are concerned it is practically a matter of waste of time to undertake such determinations. According to Prof. Zeit, the determinations are so intricate and delicate that bacteriologists have abandoned the idea of making such discovery. So that so far as bacteriology is concerned the fact that pathogenic bacteria are not found in water constitutes no reason to conclude that such bacteria are not contained in it. The science of chemistry also fails to disclose the true condition of the water from a scientific sanitary standpoint. Water may be pronounced safe by chemists and yet contain disease producing organisms, so that so far as the science of chemistry and bacteriology alone are concerned no accurate conclusions can be arrived at, and no correct determinations made which will enable one to determine accurately the sanitary condition of the water. (Long's cross-examination, Vol. 5, p. 4333; Zeit's cross-examination, Vol. 5, p. 4427; Palmer's cross-examination, Vol. 6, p. 5653.)"

Upon turning to the pages of the record quoted by counsel, we find the following:

Prof. Long on page 4333 of the record stated that he was unable to make a determination at Grafton, so far as the science of chemistry and bacteriological chemistry go, to determine the presence or absence of micro-organisms that are discharged from Chicago into the Illinois River at Grafton. In other words, Prof. Long stated that he could not tell from the sciences of bacteriology or chemistry, whether the micro-

organisms found at Grafton came from Chicago or not. He further states, "I don't know that any micro-organisms ever get to Grafton from Chicago," and on page 4332 of the record he says, "I do not know whether any of these micro-organisms started at Chicago or somewhere else."

Witnesses for complainant all testify to the same effect. The sum and substance of these statements is that if micro-organisms are found at Grafton or the St. Louis intake, it is impossible to determine by a chemical or bacteriological examination whether they came from Chicago or some other nearby point.

On page 4427 of the record, which is referred to by counsel, Prof. Zeit states the fact to be that typhoid bacilli are not found in running water. But that is the limit of Prof. Zeit's statement.

On page 5653 of the record, referred to by counsel, Professor Palmer stated as follows:

"Q. Then from the standpoint of a chemist, one is unable to determine from the sanitary chemical analysis of water, whether or not disease producing organisms contained in a polluted stream will live longer in the presence of large quantities of nitrogenous organic matter than in the absence of such nitrogenous organic matter?

"A. The chemist pure and simple is unable to determine this point.

"Q. Do your analyses of the water contained in the Illinois River and the Drainage Canal, disclose any such determination as to the longevity of the disease producing organisms in the presence or absence of other nitrogenous organic matter? A. They do not.

"Q. Do your chemical analyses of the water in the Illinois River and the Drainage Canal, disclose whether or not the disease producing organisms disappear with proportionate

rapidity to the disappearance of the total organic matter contained in that water? A. They do not.

"Q. Do the chemical analyses which you have read in evidence in this case disclose whether or not the disease producing organisms contained in the sewage, of Chicago, disappear to any extent whatever from that water?

"A. Considered merely from the standpoint of the chemist, they throw no light whatever upon this question." (5653.)

We contend there is nothing in the testimony of the witnesses on the pages indicated by counsel which shows that "so far as the science of chemistry and bacteriology alone are concerned," no accurate conclusions can be arrived at and no correct determinations made which will enable one to determine accurately the sanitary conditions of the water. It is admitted by witnesses for complainant that chemistry and bacteriology combined are a sufficient basis upon which to form a conclusion as to the sanitary condition of water. This is an uncontroverted fact which has been testified to by nearly all the experts.

Counsel on page 89 of their argument enumerate the pathogenic bacteria found in the Illinois River. When counsel state, that it is striking that pathogenic bacteria were found in the Illinois River "when you take into consideration the fact that bacteriologists have been using every possible means to discover some way by which pathogenic bacteria might be readily determined in the water," this statement is not in accord with the evidence introduced in this case. It is true, that it is agreed by all the witnesses that it is difficult to discover typhoid bacilli in running water, but as to the particular pathogenic bacteria which are referred to by counsel as having been found in the Illinois River, Prof. Zeit had no difficulty whatever in discovering same. Counsel fail to further quote from Professor Zeit's testimony, which will be found on page 4416 of the record, and which ought to supple-

ment that portion of the testimony quoted by counsel, as follows:

"A. I found that there was a gradual decrease in the number as well as in the kind of pathogenic or disease producing bacteria in the water specimens submitted as we got further away from Chicago. Further, I found that bacteria that are generally known as sewage bacteria or saprophytic organisms gradually decrease as we approach Upper Peoria. The number as well as the kind of disease-producing bacteria, as well as the sewage bacteria, is continually decreasing to this point, and the absence of pathogenic effect in animals I think is also a sufficient proof that the zone of bacterial self-purification, which every river has which has become polluted, must be located somewhere above or near Upper Peoria."

Counsel in enumerating the pathogenic bacteria found in the Illinois River failed to state that the same bacteria were also found in the Mississippi and Missouri Rivers by Professor Zeit. Professor Zeit also testified that he found the proteus bacilli vulgaris and the bacilli tetani in the Spoon River near Havana. The Spoon River is a tributary of the Illinois and is therefore not influenced by the Drainage Canal.

Professor Zeit testifies that there is no difficulty in finding these pathogenic germs if they are at all present in water.

The method employed by Professor Zeit is as follows: One cubic centimeter of the sample of water was added to five cubic centimeters of nutrient bouillon. This bouillon is a media on which the pathogenic germs can exist and thrive. The mixture was then kept at a temperature of 37° centigrade for twenty-four hours. Disease producing bacteria are favored and multiply at this temperature, whereas water bacteria would be held back. The result of the carrying out of this method is that if there had been one pathogenic germ in the sample of water after twenty-four hours the one germ

would have produced billions of the same germ, which would produce disease or death. (4429.)

The above process, which is referred to by witness as the enriching process, could not of course cause the pathogenic bacteria to multiply unless such pathogenic bacteria were present.

The culture thus enriched was injected intraperitoneally into guinea pigs and if the animal died cultures were taken from the blood, the spleen and the lymph glands, and the species of bacteria causing the death was ascertained.

While it is true that guinea pigs died after receiving injections of the water from the Drainage Canal, such injected water being enriched by the above process, the number of these disease producing bacteria decreased as examinations were made further down the Illinois River, and the pathogenic effect on the animals also decreased. In fact, as to the experiments with the water at Grafton, Professor Zeit says on page 4421 of this record, "intraperitoneal injections of four cubic centimeters into guinea pigs did not prove fatal. Mixed cultures one to five were non-virulent." The injection referred to was an injection of the water from the Illinois River after being subjected to the enriching process above referred to. This shows that there are no pathogenic germs in the Illinois River at its mouth at Grafton. It must be remembered that this witness testified that had there been one pathogenic germ in any of the samples taken this one germ would have produced billions during the twenty-four hours that it was subjected to the enriching process.

This test was so absolute that Professor Zeit states on page 4460 of the record that he would be perfectly willing to swallow the water of a stream, a sample of which after being enriched as above indicated failed to have any pathogenic effect on guinea pigs. This leads to the conclusion that the

water of the Illinois River at Grafton contains no pathogenic bacteria whatever.

The Missouri and Mississippi Rivers, however, so far as pathogenic bacteria are concerned, are not referred to by counsel for complainant. They contain the same pathogenic bacteria as are found in the Illinois River. That the particular species of pathogenic germs enumerated by counsel as having been found in the Illinois River are not difficult of location in running streams is indicated by tables 1, 2 and 3, reproduced on pages 4442, 4446 and 4447 of the record, respectively, showing the water specimens from the Illinois, Mississippi and Missouri Rivers for the period of investigation during the year 1901.

Professor Zeit on page 4452 states that if typhoid bacillus had been present in any of these waters when he examined same, that he believes by the enriching process that he made use of that he would have been able to find them. Thirty-eight specimens were examined from the Illinois River, 37 from the Mississippi and 36 from the Missouri River. The proteus vulgaris was found in the Illinois River 6 times, Mississippi 7, and Missouri 21.

Bac. mycoides,

Illinois River,	11
Mississippi River	15
Missouri River,	12

Bac. Mesentericus,

Illinois River,	11
Mississippi River,	19
Missouri River,	14

Bac. Megeterium,

Illinois River,	6
Mississippi River,	11
Missouri River,	9

Bac. subtilis,

Illinois River, 1
Mississippi River, 1
Missouri River, 1

Bac. liquidus,

Illinois River,
Mississippi River,
Missouri River,

Bac. enteritidis,

Illinois River,
Mississippi River,
Missouri River,

Bac. acid lactici,

Illinois River,
Mississippi River,
Missouri River,

Mic. candicans,

Illinois River,
Mississippi River,
Missouri River, 1
(4453.)

Thus we see that this same witness testifies that he found pathogenic bacteria in the Missouri and Mississippi River and it will be noted that this is the only witness that counsel quote as authority for the fact that pathogenic bacteria were found in the Illinois River. His testimony shows that from examinations made for the purpose of determining the relative pollution of the Illinois, Mississippi and Missouri Rivers that the Illinois River according to the number of pathogenic and other bacteria found, is less polluted than the other two rivers referred to.

9.

CHEMICAL CONSTITUENTS OF THE WATER DO NOT SHOW INCREASED POLLUTION OF THE ILLINOIS RIVER SINCE THE OPENING OF THE CHICAGO DRAINAGE CANAL.

We submit that the testimony referred to under this head in complainant's argument, beginning on page 91 thereof, does not sustain the contention that "the chemical constituents of the water show an increased pollution of the Illinois river since the opening of the Chicago Drainage Canal."

Much testimony is quoted showing results of chemical examinations of water at Hartford on the Mississippi River, at the St. Louis Intake, at the Missouri and Illinois Shore of the Chain of Rocks, etc., which we submit is immaterial to the determination of this controversy. The question under consideration in this case is "is the Illinois River at its mouth in a more polluted condition since the opening of the Canal than it was prior thereto?" If not, it is immaterial what the condition is at the Intake, at Hartford or at the Chain of Rocks.

Much space is also devoted in complainant's brief and also in their volume of exhibits, tending to show that the Illinois River in its upper stretches is in a polluted condition. This is also immaterial to a decision of this controversy—St. Louis is not affected by this polluted condition if the River is purified before it reaches its confluence with the Mississippi River. In other words, the only possible way that complainant could be affected by the sewage of Chicago would be by its appearance in the Illinois River at Grafton and its discharge at that point from the Illinois River into the Mississippi River and thence down the Mississippi to the St. Louis intake. We submit, however, that the Illinois River, from every standpoint, is in better sanitary condition since the Canal has been opened

than it was prior thereto. In fact, we will show by complain-
ant's own figures without regard to the testimony of defend-
ant's witnesses, that the opening of the Canal has been a bene-
fit to the Illinois River, if proper comparisons of results o
analyses are made.

The witnesses for complainant, in making comparisons o
chemical data have disregarded the fact, as shown under Sec
tion 7 of this argument relating to the bacteriological data
that the condition of a water varies with the seasons, and mak
a comparison of the chemical data obtained from an examina
tion of the water in spring with that obtained in the fall o
the year. The result of course shows an apparent increas
for the reason that the Canal was opened at a time betwee
the two seasons when the greatest variations in chemical an
bacteriological conditions in the water take place. This in
crease is shown to have taken place in every river from whic
samples were taken for examination in this case. No mentio
is made of this fact by complainants, however, and the cou
is therefore lead to believe that the increase is due to th
opening of the Canal, when such is not the fact.

Professor Keiser, whose testimony is quoted so liberall
by complainants in their argument under this head, also use
the following method of comparison; he averages the chemic
determinations from the few samples obtained in the fall o
1899; then he takes the averages of the samples taken fro
January 23 to October 10, 1900; then averages the result
from samples taken in October and November, 1901. He the
takes the average of 1900 and 1901 and finds the general ave
age of those two years and makes a comparison with th
average for 1899. (See Rec. 1700 *et seq.*) We submit this
unjust and does not represent true conditions. A proper com
parison would be to take the average of samples taken in th
fall of 1899 and compare with the average of the sample

taken in the fall (October and November) of 1901. This we will now submit to the court.

Professor Keiser states on record 1707 that "nineteen samples of the water of the Illinois River from a point three miles above Grafton were collected and analyzed by the city chemist at intervals between September 6, 1899, and January 17, 1900. That was before the opening of the Canal. The average values found are as follows:

Free ammonia	.215
Nitrites	.012
Albuminoid Ammonia	.553
Nitrates	.8
Chlorine	25."

He then states on the same page that daily samples were taken in October and November, 1901, and the results were as follows:

Free ammonia	.110
Nitrites	.043
Albuminoid ammonia	.373
Nitrates	1.71
Chlorine	21.6

An explanation is here due the court, that the more free ammonia, nitrites, albuminoid ammonia and chlorine are found the more the water is presumed to be polluted. In other words, increased pollution is shown by an increase in the amount of parts per million of free ammonia, nitrites, albuminoid ammonia and chlorine. The reverse is true as to nitrates, the nitrates being the last stage occurring in the cycle of nitrification. An increased amount of nitrates therefore shows increased purification.

The above comparison shows much less free ammonia, a slight increase in nitrites (which we will show under another heading comes from a reduction of nitrates back into nitrites and in this case shows a better condition of the water), much

less albuminoid ammonia, an enormous increase in nitrates and a decrease in chlorine. This then shows conclusively, that the opening of the Chicago Drainage Canal, has had the effect of improving the sanitary condition of the Illinois River at its mouth. This is from complainant's own figures and this question will be further discussed from the standpoint of defendants' testimony under the heading "Purification of the Illinois River." We submit, however, that the above shows by the testimony of the very witness quoted in complainant's argument, that a better condition exists in the Illinois River in 1901 after the opening of the Canal than existed prior to the opening—the comparison being fair for the reason that the samples in both cases were taken in the fall of the year.

It is true that if the average of results from samples taken in the fall of 1899 is compared with the average results obtained from January 23 to October 10, 1900, that an increase is shown in the Illinois River. We will, however, show to the Court that a similar but greater increase takes place in the Missouri and Mississippi Rivers if the same comparison is made—those rivers not being influenced by the sewage from Chicago.

Prof. Kaiser testifies (1706):

"Eighteen samples of water were taken from the Mississippi River at a point above the mouth of the Illinois River. These samples were obtained at intervals between September 6, 1899, and January 17, 1900. (Before the Canal was opened.) The average values of the analyses made by the city chemist are as follows:

Free ammonia,	.069
Nitrites,	.002
Albuminoid ammonia,	.503
Nitrates	.3
Chlorines,	6.

He further states on the same page:

"Daily analyses of the water from this point were also made from January 23, 1900, to October 10, 1900. (After the opening of the Canal.) The averages obtained are as follows:

Free ammonia	.138
Nitrites	.008
Albuminoid ammonia	.587
Nitrates	.46
Chlorines,	5.0

Here then is the Mississippi River above the mouth of the Illinois at a point where the Illinois River cannot influence it—and it has more of an increase in 1900 than has the Illinois River making the same comparison—this comparison shows more free ammonia, more nitrites, more albuminoid ammonia, more nitrates and less chlorine.

Prof. Keiser testifies (1702) that "In looking over the statistics of the Health Department of the City of St. Louis, I found eleven analyses of the stream (Missouri River) are on record in the Health Department of the City of St. Louis. (These were samples taken before opening of the Canal.) The average results of these analyses were:

Free ammonia,	.080
Nitrites	.001
Albuminoid ammonia,	.657
Nitrates	.4

He further states (1703) that "After February 1, 1900, daily analyses of Missouri River water were made by the City Chemist until October 10, 1900." He then states the averages were as follows:

Free ammonia,	.142
Nitrites,	.007
Albuminoid ammonia,	1.203
Nitrates,	.5

This shows an enormous increase in every one of the above mentioned chemical constituents.

If we find the enormous increases above referred to in the Missouri and Mississippi Rivers, it is only natural that we should find a corresponding increase in the Illinois River by a comparison of the same periods. This is the increase that so much stress is laid upon by Prof. Keiser and Prof. Teichmann, the only witnesses quoted by complainant on this proposition. Prof. Keiser as above stated, testified (1707) that "19 samples of the water of the Illinois River from a point three miles above Grafton were collected and analyzed by the City Chemist at intervals between September 6, 1899, and January 17, 1900. That was before the opening of the Canal. The average values found are as follows:

Free ammonia,	.215
Nitrites,	.012
Albuminois ammonia,	.553
Nitrates,	.8
Chlorine,	25.0

He then states that the averages for the period beginning January 23rd and ending October 10, 1900, is as follows:

Free ammonia,	.272
Nitrites,	.032
Albuminois ammonia,	.509
Nitrates,	.96
Chlorine,	13.0

This shows that the opening of the Drainage Canal had a purifying effect on the Illinois River for instead of an increase in every one of the above mentioned chemical constituents, we only find an increase in free ammonia and nitrites, there being a decrease in albuminoid ammonia and the chlorine being reduced from 25 to 13 parts per million. There is also an increase in nitrates, showing that a better sanitary condition prevails.

This shows that our contention is correct—that the difference in results in the early part of 1900 as compared with the latter part of 1899 are due to seasonal variations, because we have shown that the same conditions exist as to the Mississippi and Missouri Rivers as are found on the Illinois. Complainants take advantage of this, however, to make comparisons, owing to the fact that the Drainage Canal was opened just at a time when these chemical and bacteriological results are naturally higher. But the fact that the testimony introduced by complainant itself shows a similar condition of affairs existed on the Missouri and Mississippi Rivers is sufficient evidence that the comparisons made by complainant should not have any weight with this Court for the reason that they are not proper.

We respectfully refer the court to the record at pages 1697 to 1710, where it will be seen that Prof. Keiser comes to his conclusions by ingenious methods of making averages of averages and comparing samples taken at one season of the year with those taken at another season. His conclusions are therefore not warranted by the facts.

As to the conditions at the Intake, Chain of Rocks, Hartford, etc., enough has been said above to show that if there was an increase in 1900, such increase must have come from the Missouri and Mississippi Rivers for the reason that we have shown by complainant's own evidence that an increase took place in both of those rivers during the year 1900, higher in comparison than took place in the Illinois River.

Prof. Keiser, the record shows, was not sufficiently conversant with conditions along the Illinois River to form any definite conclusion as to its sanitary condition at Grafton. In making his comparison of the Illinois River prior to the opening of the Canal with conditions subsequent thereto, he made use of Prof. Long's tables of analyses as the same appear in the published report of the Illinois State Board of

Health, and from his tables and those of Prof. Long he testifies that the results would indicate an increase of pollution of sewage since 1900 at Peoria. (1076.) The record on page 1116 shows that he compared Wesley, which is situated below Peoria and below the outfalls of the sewers of that city and the cattle sheds with "The Narrows," which is above Peoria —taking the Wesley analyses for 1900 and the "Narrows" analyses for 1899. On cross-examination he says:

"Q. Then, you don't know that—you didn't know that Wesley was located below Peoria?

A. I didn't know where it was exactly. I don't know whether the sewage of Peoria got into the river at Wesley. I thought it was considerably below, if anything. I didn't think it was right in the town of Peoria." (1120, 1129.)

This witness also testified (1142) that "I know of no large towns that run sewage into the tributaries of the Illinois." This, notwithstanding that numerous large cities are situated on the Illinois River and its tributaries. He also confesses (1080) that he never traveled up the Illinois River with a view of determining the source of its water supply. In fact he admits he knows nothing about the Illinois River except such as he gathers from a study of maps, etc. This is also true of Prof. Teichmann. It must also be remembered that in the testimony quoted by counsel for complainant under this heading Profs. Keiser and Teichmann base their conclusions on the fact that the chlorine in the Missouri is from the Kaw River and not from sewage, when, in fact, as shown hereafter the reverse is true. It must also be remembered that the only examination made prior to 1900 was a few samples taken sporadically. We therefore submit that the testimony of witnesses or defendants which relates to examinations made as far back as the year 1886 and also consisting of daily and weekly samples taken one year before the Canal was opened, is deserving of more weight than that introduced

by complainant. We therefore refer the court to that portion of this argument numbered 30, entitled "Purification of the Illinois River," where the testimony of witneses for defendants is referred to and which fully answers all contentions made by complainant.

10.

"DISAPPEARANCE OF BACTERIA IN RIVERS."

This part of complainant's argument, beginning on page 127, is also discussed under various other heads, such as "The Doctrine of Self-Purification of Streams Discussed," beginning on page 243 of complainant's argument, so that we feel that whatever might be said under this head at this point would be merely a repetition of what appears elsewhere.

11.

"MICROSCOPIC OBSERVATIONS ON THE WATERS OF LAKE MICHIGAN, CHICAGO DRAINAGE CANAL, AND ILLINOIS AND MISSISSIPPI RIVERS."

Under this heading on page 129 of argument, counsel state that Prof. Whipple discovered certain micro-organisms in the intake of the St. Louis water works that were indigenous to Lake Michigan only, counsel further stating, on page 130, "demonstrating that *living* organisms contained in the waters of Lake Michigan passed from the Canal into the river and thence into the Mississippi and the intake of the St. Louis water works." It must be remembered in this connection that micro-organisms referred to are not bacteria, but minute forms of life, too small to be identified without the use of the microscope, but not as small as bacteria. It will be noted

also that counsel refer especially to the synedra pulchella variety sub. prolongata as having been found in the intake at St. Louis.

Prof. Whipple says:

"The most abundant organisms present in Lake Michigan during the period covered by these examinations were synedra and tabellari which belong to the plant kingdom, known as the diatomaceae, or to use a shorter expression, they are known as diatoms." (1924.)

"A diatom is a unicellular plant and perhaps its most important difference from other unicellular plants is the fact that its cell wall is so *impregnated with silica* that it is practically an *indestructible thing.* That is, a diatom might be described as a little plant cell made of *glass.* The living matter lies within this siliceous cell and after the death of the cell the walls of the cell remain just as they appear during life. In fact, they may be considered as fossil remains of a plant, and there are in existence today geological deposits which are composed almost entirely of diatomacious cells.

Q. Are they considered more hardy and more likely to survive the voyage from Lake Michigan down the various water courses, to the intake at St. Louis, than the other microscopic organisms, or not?

A. Yes, sir; these cells being indestructible, or practically so, could be identified after a long passage through a river, and this cell wall being a strong protection to the cell offers more favorable resistance than many of the microscopic plants, such for example, as the blue-green algae or the green algae even.

Q. Where are these diatoms most likely to be found?

A. Diatoms are likely to be found in almost any kind of fresh water, but there are thousands of species of diatoms, and the particular diatoms with which we are concerned in those examinations, namely, asterionella, synedra, melosira,

cyclotella, stephanodiscus and the others mentioned, are more commonly found in ponds and lakes and such bodies of water, than they are elsewhere." (Whipple, 1922.)

What the witness states about finding these particular micro-organisms was as follows:

"There was an organism which I will describe as synedra pulchella variety sub prolongata, which was found at the Intake of the Waterworks at the Chain of Rocks, and which was found also in the water of Lake Michigan, but was not found in the water of the Missouri River, or the water of the upper Mississippi River, or in any of the tributaries of the Illinois River unless we consider the Chicago Drainage Canal as being a tributary." (1924.)

It will be noted on pages 1928 and 1929 of the record that a great many micro-organisms were found in the intake or the settling basin, which were indigenous only to the Missouri or to the Mississippi River and were not found in the Illinois River at any point. For instance, this witness states on page 1928 as follows:

"The conclusion from these figures being that for the most part the melosira found at the intake of the St. Louis water works and at the Mississippi River near the Illinois shore were derived not from the Illinois River or from Lake Michigan or from any of the tributaries of the Illinois, but rather from the Mississippi River above Grafton." (1928.)

"The conclusion being that these cyclotella found at the intake of the St. Louis water works at the Chain of Rocks, came for the most part, not from the Missouri River, but from the Mississippi River and the Illinois River, and only to a slight extent from Lake Michigan. The cyclotella found in the Illinois River at Grafton being derived not from Lake Michigan, but from one or more of the tributaries." (1928.)

And on page 1929 of the record as follows:

"From which I conclude that the majority of the stephano-

discus—found at the intake of the St. Louis water works, and at the Illinois shore opposite the Chain of Rocks, were derived not so much from the Missouri River or the Illinois River, as from the Mississippi River above Grafton." Witness then states: "These organisms just enumerated, or these diatoms just enumerated are not as likely to be found in the waters of running streams, unless these streams are fed from lakes or ponds, or similar ponds of water." (1922.)

Witness then states that there is no geographical limitation to the existence of the synedra and that they could exist in ponds and lakes and that they could also exist in the State of Illinois, the State of Illinois being within their geographical distribution. The same is also true of the tabellaria. It will therefore be seen that since the synedra and tabellaria were found in the Illinois River and also in Lake Michigan, and as above stated, these two micro-organisms are found in ponds and lakes and not in running streams, and taking into consideration also the fact that along the Illinois River are to be found many ponds and lakes, it is impossible to determine whether the micro-organisms found at the mouth of the river came from Lake Michigan or from one of the other lakes or ponds draining into the Illinois River.

But it is not material whether these particular micro-organisms came from Lake Michigan or not. The evidence discloses as above quoted, that certain micro-organisms were found at the intake which must have come from either the Mississippi or Missouri Rivers and were never found in the Illinois River. These micro-organisms are harmless, and in the case of the micro-organisms alleged to have come from Lake Michigan, it must be remembered that the evidence shows that they are diatoms and have a cell-like covering composed of silica, which practically makes them indestructible. Prof. Whipple testifies on page 2016, referring to the synedra and tabellaria, the particular organisms or diatoms which it is

claimed were found in the intake and are only indigenous to Lake Michigan as follows:

"Q. Then all other considerations being equal, you don't think that the fact that the supposed organisms traveled through 22 or 24 miles of sewage, of any consequence?

A. Practically not in this case, or in the case of these two organisms so far as they refer to any examinations that have been made, for the reason that in the examination which I have made, I have not attempted to differentiate between a *live synedra* and a *synedra not capable of developing.*"

Also on page 2107 of the record, this witness testifies as follows:

"I have stated that in the microscopical examinations which I have made, I have not taken into account the actual life of the synedra and the tabellaria present; I have simply ascertained the number of the cells of the organisms regardless of whether they were-you may say dead or alive." (2107.)

Taking into consideration all of the evidence on this subject, we come to the following conclusion: That two species of micro-organisms, synedra and tabellaria, were found at the intake; that these micro-organisms were not found in either the Mississippi or Missouri Rivers and are indigenous to Lake Michigan; that these micro-organisms are usually found in ponds or lakes and may have come from ponds or lakes tributary to the Illinois River; that they are covered with a cell, consisting of silica, which is practically indestructible *and that no determination was made as to whether they were dead or alive when found in the intake.* This then would have no more bearing on the case than if a grain of sand was found at the intake which was peculiar to the waters of Lake Michigan, for these micro-organisms are harmless and like this grain of sand, are practically indestructible. The most that can be said from this experiment is that if these micro-organisms came from Lake Michigan, that Lake

Michigan water flows past the intake at St. Louis. There is no controversy as to this point whatever, and it is not remarkable that a micro-organism that is practically indestructible, should be found at St. Louis, even though it had traveled all the way from Chicago, especially taking into consideration the fact that when found it is not *known whether it was dead or alive*. This experiment has no bearing on the proposition that pathogenic germs may survive the journey, for the reason that there is no analogy between the two.

It must be remembered that what counsel say on page 120 referring to the fact that there would not be any increase in number nor would these micro-organisms disintegrate to such an extent as to be unrecognizable during transit, refers to the transportation of the samples of water from the point at which they were taken to the laboratory of Prof. Whipple and not to the journey from Chicago to St. Louis through the Canal and Illinois River. (See Prof. Whipple's Testimony on page 2909.)

Prof. Whipple testified that he only examined three samples of Missouri River water and that he failed to find the synedra pulchella, variety sub prolongata in these samples. The witness admits that had a more extensive examination been made the synedra and tabellaria might have been found. He testified on page 2128 of the record as follows:

"Q. If additional samples of water had been taken at other times during the year 1901 and examined microscopically to ascertain the presence of the micro-organisms to which you have referred, is it not probable that these other samples of water would have disclosed (taken at Bellefontaine or in the Mississippi River above Grafton) would have disclosed the presence of the two genera which you stated were not found at those places?

A. I can't say that it is probable that they would, but they certainly might have disclosed it.

Q. They might have done so?

A. Might have done so, yes sir." (2128.)

Had a more extended examination been made of the Missouri River it is probable that these two varieties of diatoms would have been found in that river. Mr. Whipple states that there is no geographical limitation to the existence of these micro-organisms. At all events, the evidence is too meager on which to base the assumption that these two particular organisms came from Lake Michigan and not from the Illinois, Mississippi or Missouri Rivers.

Whether these particular organisms came from Lake Michigan is immaterial from the reason as above stated they are practically indestructible and it is not known whether they were dead or alive when they reached the intake of the St. Louis water works. This experiment casts no light on any of the issues involved in this controversy.

12.

"PRODIGIOSUS."

One barrel of prodigiosus culture was deposited in the Mississippi River below the mouth of the Illinois on August 31, 1900. Samples of water from that point down to the St. Louis intake were taken continuously to determine whether such bacillus could be found.

On page 906 of the record witness states that samples were taken from the very boat from which the deposit was made, on its return trip to St. Louis. These samples were taken afterwards every few hours during the day at Alton, Hartford, Illinois shore, Chain of Rocks, intake tower and Missouri shore. On September 3rd one bacillus was alleged to

have been found at Alton. This experiment was repeated on September 20th and the same precautions taken to discover the bacteria after its introduction in the water with the result that four days afterwards the organism was alleged to have been found in a sample of water collected on the Illinois shore at the Chain of Rocks. On October 18th, 28 days afterwards, another bacterium was alleged to have been found in the laboratory tap at the City Hall. On October 24th, 34 days afterwards, another bacterium was alleged to have been found at the Illinois shore, Chain of Rocks. One month therefore elapsed between the finding of the first bacterium at the Illinois shore and the second, which necessarily leads to the preposterous conclusion that as a result of the deposit of one barrel of culture containing this bacteria below the mouth of the Illinois in the Mississippi, such bacteria were passing the Illinois shore at the Chain of Rocks, for a continuous period of one month.

The experiment was again repeated on November 6th when 167 barrels of prodigiosus culture were deposited in the Drainage Canal at Lemont, 25 miles distant from Chicago, containing over 1,000,000,000 prodigiosus bacteria per cubic centimeter, there being about 4 cubic centimeters to a teaspoon full. (783.) Immediately after the introduction of this bacteria in the Canal *hourly* samples were taken at the *controlling works* of the Canal, at *Joliet*, at *Peoria*, at *Grafton* and at the *intake*. The date on which the bacteria were introduced in the Canal was November 6th, and the first bacterium alleged to have been found was on December 4th, nearly one month afterwards, and this was found at the intake tower, a distance of 340 miles from the place where the broth culture was originally dumped. That the bacterium found at the intake was not one of the bacteria deposited in the Drainage Canal, is evidenced by the fact, that during this entire period of over a month while hourly examinations were

made of the water at such close points as the controlling works of the canal, which is only a few miles from the point at which the bacteria were deposited, and also at Joliet, which is about 13 miles from the point at which the bacteria were deposited, *no bacillus prodigiosus whatever were found*. On December 6th, and also on December 7th, one bacterium was alleged to have been found at Grafton in the Illinois River.

Assuming however that the bacteria found were those that were introduced in the Drainage Canal, we can come to no other conclusion but that it takes one month for the water of the Drainage Canal to reach the mouth of the Illinois River at Grafton, the distance being about 300 miles, while the distance from Chicago to the intake of the St. Louis water works is 367 miles.

The evidence discloses that the bacillus prodigiosus is a much hardier bacterium than the bacillus typhosus. The fact that only one alleged bacillus prodigiosus was found at the intake tower or at Grafton, after the enormous amount placed in the Drainage Canal, is an indication that even the bacillus prodigiosus was unable to survive the passage from the Drainage Canal to the St. Louis water works. When we take into consideration that the experiments made by Dr. Ravold, principal witness for complainant show, according to his own testimony on record (757), that in the dark, in non-sterilized living waters, the bacillus prodigiosus lived from 31 to 53 days and the bacillus typhosus from 24 hours to 21 days, it will be seen that the life of a bacillus prodigiosus is at least double that of a typhoid bacillus. The only conclusion that can be reached from the experiments is that typhoid bacilli cannot survive the journey from Chicago to St. Louis, especially considering the fact that in traveling from Chicago to St. Louis, it would be necessary for such typhoid bacilli to remain in the sewers in the City of Chicago for a considerable length of time, and in addition

to the alleged journey taken by the bacilli prodigiosus deposited in the Canal by Dr. Ravold, would have to make the additional journey from the Chicago sewers through the Chicago River and down the Canal to Lemont, a distance of at least 30 miles, the water for those 30 miles being sewage polluted, and therefore least conducive to the life of typhoid bacilli, as they die more readily in sewage polluted water than water without such pollution.

In each of the instances in which witness claims to have found the bacteria, it will be noticed that he only found one in the samples of water examined.

On this subject Prof. W. P. Mason, witness for defendants, testifies on page 6909 of the record, as follows:

"I have read of the experiments made with the bacillus prodigiosus by Dr. Ravold. (Question asked assuming all the conditions as testified to by Dr. Ravold in relation to said experiment.) "Assuming all of the facts stated to be true, my opinion is that in view of the large number of the bacillus prodigiosus introduced and the small number found the results of that experiment show a very considerable death rate of the bacillus of typhoid fever under the same circumstances. In my opinion, it seems that the importance attached to this experiment is to show that to the extent that a bacillus prodigiosus represents a bacillus of typhoid fever, a very large death rate has been proven as occurring among the bacilli of typhoid fever under those circumstances."

In referring to the experiment made by Dr. Ravold, Prof. John H. Long on page 4259 of the record in answering to a similar hypothetical question states as follows:

"Considering the longevity of the typhoid bacillus, as measured by the longevity of the bacillus prodigiosus, which consideration in no way involves a knowledge of bacteriology, but simply a knowledge of arithmetic as set forth in this question, I would say that the suppositions advanced in this ques-

tion indicate that the longevity of the bacillus prodigiosus, and of the typhoid bacillus as compared with it, is so extremely slight as to make the probability of a germ of this character being able to survive a passage from the Drainage Canal to Grafton so remote as to be entirely unworthy of consideration."

"Measuring the longevity of the typhoid bacillus by that of the bacillus prodigiosus, from the fact as stated in the question that in the large number of examinations made at Lockport and Joliet and Peoria, no prodigiosus bacteria were found at all, and from the further fact that at the mouth of the river and at the intake tower at the Chain of Rocks, and in the water supply of St. Louis, the small number mentioned were obtained, and none at all in a period before the fourth of December, and none after the eighth of December, the possibility is extremely remote, and it is practically improbable, that a typhoid bacillus with longevity and virility as measured by that of the bacillus prodigiosus, could ever survive the passage down the Drainage Canal and the Illinois River and enter the water supply of St. Louis."

Prof. Jordan when asked a hypothetical question assuming the conditions of the experiment made by Dr. Ravold, testifies as follows on page 6150 of the record:

"In my opinion this experiment sheds a certain amount of light on the probable longevity of a typhoid bacillus under the conditions as stated. This is true for the reason that the relatively insignificant findings of bacillus prodigiosus, assuming identification to be correct, indicate that this organism, while in a fairly hardy saprophytic form, does not live long in the river water, and that the typhoid bacillus, which is beyond doubt a more highly specialized parasitic form than bacillus prodigiosus, would not survive as long as the latter. The experiment, in my judgment, affords strong confirmation of the evidence already derived from a study of the death rate

among colon bacilli in the water of the Illinois River. Since bacillus prodigiosus dies off so speedily and in such large numbers, the typhoid bacillus would be less likely to survive exposure to these same conditions." (6150.)

Professor E. G. Smith was asked a similar question and replied in substance (6749): "The longevity of the bacillus prodigiosus is not necessarily a measure of the longevity of the typhoid bacillus. The bacillus prodigiosus is known to flourish at ordinary temperature, while there is no evidence that the typhoid organism can flourish or develop in water.

"If this organism had remained in the water for any length of time, the observers at Joliet and Peoria would have found them, while the results show that they were not found above Grafton. Even if they had been found in constantly diminishing numbers, it would be reasonable to assume that if those organisms were the one that actually made their way down the river, they would have been found in larger numbers in the samples taken at Joliet and Peoria than at Grafton. As a matter of fact, there is no record that they were ever found at the two stations on the upper river. It seems to me to be a contribution to the study of the self-purification of that stream. It is an evidence for the stream being rid from them rather than anything else."

Professor Robert Zeit, on page 4478, stated in answer to a similar hypothetical question as that put to Professor Long: "In the second place, the great numbers that were poured into the Canal and the practical absence of them afterwards would only illustrate what the self-purification of rivers means, because this germ grows best at room temperature. It would, perhaps, not die as easily in water as a typhoid bacillus, because it could probably exist better than a typhoid bacillus under those conditions; and I think it would prove that if it is true that the prodigiosus disappears under such

conditions, that it would be much more true of the typhoid bacillus."

In regard to the life history of this bacterium we desire to call the Court's attention to a misstatement of the evidence on this subject on page 132 of complainant's argument. Counsel state that "in the refrigerator in the dark it (prodigiosus bacillus) was found to live for a period of 31 to 53 days, and in the above non-sterilized water, exposed to sun light it survived 11 days, while the bacilli typhosus in the same water under similar circumstances, lived from 10 to 21 days." This would lead the Court to believe that bacillus prodigiosus exposed to sun light survive 11 days and the bacilli typhosus in the sun light in non-sterilized water survive from 10 to 21 days, thus making the life history of the bacillus typhosus twice as long as that of the prodigiosus. The fact is that the testimony has been misquoted by Counsel. On page 786 of the record Prof. Ravold testified "exposed to sunlight in samples of various waters, not sterilized, it lived from 2 to 10 days." This witness did testify that in the refrigerator in the dark bacillus prodigiosus lived for a period of 31 to 53 days, but he also testified that the bacilli typhosus under similar circumstances live from 10 to 21 days, which would make the life of the bacilli typhosus about three times as short as that of the prodigiosus. In other words, in the quotation above referred to by counsel the statement "While the bacilli typhosus in the same water under similar circumstances live from 10 to 21 days" means in the refrigerator in the dark and does not mean "exposed to the sunlight."

From an examination of all the evidence in this case relating to the experiment made by Dr. Ravold, we can but come to the conclusion that there is no evidence to show that the organisms placed in the canal at Lemont were afterwards found in the Mississippi River. If it be admitted that those found in the Mississippi River were a portion of those placed

in the Canal at Lemont, then the experiment proves that i takes 34 days for a bacterium to make the journey from Le mont to Grafton, a distance of 300 miles. If we add to thi the time consumed by typhoid bacilli in making the journe through the Chicago sewers, down the Illinois River an Drainage Canal to Lemont, and then from Grafton to the in take, which is about 67 miles additional, and figure that th bacteria in making the whole journey referred to traveled a approximately the same rate as that beginning at Lemont an ending at Grafton, an addition of ten days to the 34 day would be an extremely fair calculation in determining th amount of time consumed by bacteria in traveling from th sewers of Chicago to the intake at St. Louis. It is admitted b *all* the witnesses for complainant that a typhoid bacillus woul not retain its vitality for that number of days. The sma number found at the intake also shows that even the bacillu prodigiosus which is hardier than a typhoid bacillus, did no survive the journey.

13.

THE MISSOURI RIVER IS NOT SUBJECTED TO THE DRAINAGE FROM SALT BEDS IN KANSAS, THUS PRO DUCING LARGE QUANTITIES OF CHLORINE IN TH RIVER.

Under this heading, counsel state on page 137 of their ar gument that the Missouri River contains less chlorine tha the Illnois River and more than the Mississippi River an that the chlorine in the Illinois is explainable only from th enormous population of Chicago, and the Sanitary Distric of Chicago.

In this connection we respectfully refer the Court to pag 5969 of the record where Prof. Jordan's table discloses th fact that the average amount of chlorine found in the Illinoi

River at Grafton for the year 1900, was 9.8 while the average amount found in the Missouri River for the same year was 15.4. We also find that the chlorine in the Illinois River at Grafton for the year 1899 was 18.3—thus showing that after the opening of the Canal there was less than half the amount of chlorine that was found therein prior to the opening of the canal. On the other hand the chlorine in the Missouri River for 1899 is the same as in 1900, namely, 15.4.

As indicated by counsels' argument, witnesses for complainant do not take chlorine into consideration in forming their opinion as to the sanitary condition of the Missouri River, for the reason that they state the chlorine therein comes from the Kaw River which joins the Missouri at Kansas City and which runs over salt beds in Kansas.

Prof. Teichmann, at page 1273 of the record in speaking of a chart before him, states:—

"If at this time the nitrites of the Missouri River would be as high as those found in the Mississippi River at Hartford, or higher as was shown by the free ammonia, we would ascribe the higher free ammonia in the Mississippi River to sewage pollution, but the nitrites are lower, and since the high chlorines in the Missouri River *are not attributable* to sewage pollution of the towns and cities on the upper Missouri but are proven to be due to the *drainage of the Kaw River, which runs in to the Missouri River at Kansas City*, due to the drainage of the Kaw River through districts—vast areas in Kansas of salt beds, it is to be concluded that the sanitary character of the Missouri River was better during this period than that of the Mississippi River after it was joined by the Illinois River and increasingly polluted by the Illinois River." (1273.)

We will show hereafter that the Missouri River is more polluted than the Illinois, but quote the above testimony to show to the court the importance of the question of the source

of the chlorine in the Missouri River. Counsel for complainant appreciate the importance for they devote an entire section of their argument to this very question. Witnesses for complainants base all of their opinions as to the sanitary character of the Missouri River on the assumption that the chlorine found therein originates from salt beds instead of the sewerage from the towns along its banks.

Prof. Keiser, on page 1110 of the record says:

"Q. Then when you gave it as your opinion as to the possibility of the water coming from the Missouri River at Bellefontaine, and the waters coming from the Chain of Rocks, the Illinois shore, you had different standards in your mind?

A. As regarded chlorine; yes." (1110.)

Prof. Teichman at record 1530 states that when the Missouri River water gets to Bellefontaine he is not able to state what percentage of the chlorine which he found came from sewage and what percentage from the Kaw River.

"Q. Whether the percentage from the sewage was larger than the percentage that came from the Kaw, are you able to ascertain chemically? A. No, sir.

Q. What is the size of the Kaw River?

A. Well, I could not tell you.

Q. What is the volume of water?

A. I have no data at hand just now.

Q. Compared to the waters of the Missouri River?

A. I have no data at hand just now to answer that.

Q. Have you ever had any data at hand? A No, sir.

Q. Then, if the size of the Kaw River was smaller than the Missouri River in comparison with the Missouri River, would not high chlorines in the Kaw River go down when it reached the Missouri River? A. Yes, sir, they would." (1531.)

"Q. Doctor, in the absence of the known volume of the

Missouri River and of the Kaw River, do you take into consideration the sewage contamination from Kansas City, Mo., and Kansas City, Kansas, as to the chlorines?

A. *Well, I did not in this case.* I admit that a definite conclusion could have been drawn if the quantity of chlorine coming from the sewage into the river could have been ascertained, but that was an impossibility, and on the other hand, the Kaw River showing such tremendous high chlorines, I considered it a natural conclusion that there must be some effect of the high chlorines in the Kaw on the increase in the Missouri River." (1538.)

"Q. Then drawing your conclusions you eliminate the volume of water in the Kaw, the volume of water in the Missouri and the sewage of Kansas City?

A. As I said, I based conclusions that I drew on the high chlorines in the Kaw River which had to go somewhere, and to show their effect on the Missouri River.

Q. Did you eliminate those three elements that I speak of in arriving at your conclusion?

A. I saw that more accurate conclusions could have been drawn if all those facts could have been ascertained, and in conjunction with the fact of those high chlorines in the Kaw River *should have been taken into consideration.*

Q. My question is, did you eliminate those three essential facts from your opinion or conclusion; did you not?

A. *Yes, sir.* (1539.)

"I cannot say what proportion of the increase of chlorine below Kansas City is due to the Kaw River and what to the Kansas City sewage. I don't know whether 90 per cent. of it is due to the sewage or not.

Q. Doctor, why didn't you take into consideration the sewage from Kansas City in your conclusions in regard to chlorine?

A. I had no available data. I could not obtain them would have necessitated an investigation which I could undertake at that time.

In none of my investigations have I taken into consid tion the sewage discharge of Kansas City, in calculating chlorines for the Missouri River. It was because I could obtain the data that eliminated the sewage of Kansas entirely from my consideration. I relied upon the condi of the Kaw River as found, to justify the approximate clusion." (1543-4.)

It will be seen by the above testimony that Prof. Te mann bases his entire conclusions on the potability of Missouri water on the question as to the source of the rine. If the chlorines came from Kansas City sewage, his conclusions would be different.

Prof. Keiser, in making comparisons of the Illinois, souri and Mississippi Rivers, on page 1721 of the rec states that he does not use the chlorine determinations in Missouri River, "because it wouldn't have helped any" ow to the fact that the Missouri River chlorines come from beds.

On page 1722 he says:

"As a chemist, and without reference to this questio I had been called upon to analyze a sample of Missouri R water, not knowing that it was Missouri River water, con ering the high chlorine in that sample, I would have inclined to condemn that water as unpotable."

Counsel quote, on page 125 of their argument, the fol ing testimony from Dr. Teichmann:

"Thus, considering the high chlorines in the Missouri companied with low free ammonia and nitrites, we conc that the polluting matter contained in the Missouri R is due to vegetable decomposing matter, and to salt deri from the salt beds drained by the Missouri River, ra

than from animal origin. This being true [which we will show is not true], the increase in chlorines, free ammonia and nitrites in the waters of the Mississippi River at the intake, demonstrate clearly and forcibly that the increased pollution is due to the effect of the opening of the Drainage Canal upon the waters of the Illinois River." (Teichmann's Testimony, 1209, *et seq.*)

If it is proved that the chlorines in the Missouri are from sewage instead of salt bed origin, then Mr. Teichmann's conclusions must be erroneous and founded upon incorrect data.

Only two samples were taken by the complainant in the Kaw River. (1250.)

There is nothing in the record to show where the samples taken by complainant in the Missouri River were taken. (1534.) No sample was taken above Kansas City, Mo., and below the entrance of the Kaw River, in the Missouri River. Three samples were taken below Kansas City, however. Witness Teichmann does not know just where these samples were taken and if the sample taken below the mouth of the Kaw was taken in such a portion of the Missouri as would insure a commingling of its waters with the Kaw. (See 1535, *et seq.*)

Prof. Whipple says:

"From what I know of the existing conditions on the watershed of the Missouri River and from the fact that there are certain salt deposits, and from analyses which I have seen showing the indication of such salt deposits, of the effect of such salt deposits on the water of the Kaw River, it is my opinion that the chlorine in the Missouri River, in its low reaches, cannot be used as an index of pollution, although part of it may be derived from sewage pollution, because the effect of the chlorine from the salt deposits, would simply mask any chlorine from sewage pollution, and in that

particular case the chlorine could not be used to determine whether or not the water was sewage polluted." (2680.)

Prof. Keiser, witness for complainant, testified as follows:

"I have been informed by the city chemist of the City of St. Louis, Dr. Teichmann, here, that one of the tributaries of the Missouri coming in at Kansas City has gone across salt beds in Kansas, and that it is very highly charged with chlorine, and that is the reason for chlorine in the Missouri River. I never made any analysis of this Kansas River.

Q. Now, if it should appear by analysis that the river from Kansas coming in from Kansas City, which I believe is called the Kaw?

A. Yes, I think that's it.

Q. That if it did not run any higher in chlorine than the waters of the Missouri River above that point, then the theory as to chlorine constituents coming from Kansas would not obtain?

A. That is so, I agree to that. (1107.)

Following this admission by complainant's witness, defendants, for the purpose of making a thorough examination of the conditions of the Kaw River and its effect on the Missouri River so far as an increase therein of chlorine, sent James M. Quinlan and Frank C. Burke to the Kaw River and the Missouri to take samples to be examined for chlorine. Their testimony will be found on page 4083 of the record. These samples were taken from the Kaw River on the 26th, 27th and 28th days of May, 1903. Three samples were taken on each day—the samples taken on each day being cross sections, one being taken fifty feet from the right bank; one from the center and one fifty feet from the left bank. On the 22nd, 23rd and 25th of May, they also took samples in the Missouri River, one mile above the mouth of the Kaw, no sewers from Kansas City, Kansas, or Kansas City, Missouri, emptying

into the Missouri above the point where the samples were taken. Three samples were taken daily at the above point, being also cross sections. Nine samples were taken on three different days below the mouth of the Kaw River, in the Missouri River, below the sewers of Kansas City. Three samples were taken about a mile below where the Kaw joins the Missouri but above the sewage discharges of Kansas City. The river at that time was at its normal stage. (4090.) The samples so taken were sent by express to Prof. Long.

Special determinations were made by Prof. Long to determine the amount of chlorine in these samples the general averages of the nine samples taken at each point being as follows:

Kaw River, 1½ miles above Kansas City, Kas.,	9.71
Missouri River above confluence with Kaw,	10.67
Missouri River below mouth of Kaw,	10.97
Missouri River, below Kansas City,	12.31

"The averages drawn from these tables show a considerably larger figure for chlorine below Kansas City than in the Kaw or in the Missouri above Kansas City. The excess of chlorine below Kansas City being more than can be accounted for by any addition from the Kaw, and showing the fact that a certain proportion must come from the stock yards industries, and the sewers of Kansas City." (Prof. Long, 4247.)

Prof. Long testified that he was familiar with the Kaw from its mouth for a distance of 100 miles or more west. That he lived for a number of years on that river and has been on it at numerous points. (4242.) The volumes of the Missouri and the Kaw Rivers were testified to by this witness, he having secured the information from the engineer of the United States Geographical Survey at Washington, by whom the gaugings were kept and reported.

The volumes of these rivers for the last week in May, 1903, is given in cubic feet per second as follows:

For the Kaw:	For the Missouri:
May 24, 1903, 51,000	May 22, 1903, 125,000
May 25, 1903, 49,600	May 23, 1903, 145,000
May 26, 1903, 39,100	May 24, 1903, 184,000
May 27, 1903, 63,500	May 25, 1903, 198,000
May 28, 1903, 72,200	May 26, 1903, 226,000
	May 27, 1903, 242,000
	May 28, 1903, 310,000

This table shows that the volume of the Missouri River is much greater than the volume of the Kaw throughout this period, and the amount of chlorine in the Kaw, taking its volume into consideration, cannot act to increase the amount of chlorine in the Missouri above the figure given for the Missouri above Kansas City, and Prof. Long so testified at record 4248.

We respectfully submit that this examination of the Kaw River by defendants demonstrates that the chlorine in the Missouri River should have been taken into consideration by the experts in their determination of the sanitary quality of the waters of that river, and that it conclusively shows that the sewage from Kansas City and other towns situated below Kansas City, furnishes the high chlorines in the Missouri River instead of such chlorines coming from the salt beds of the Kaw.

The conclusions of complainant's witnesses are therefore wrong, and we see from the evidence above quoted that Dr. Teichmann and Prof. Keiser admit such to be the fact.

14.

MIXING OF THE ILLINOIS, MISSOURI AND MISSISSIPPI RIVER WATERS AT AND ABOVE THE CHAIN OF ROCKS.

It must be noted that counsel in referring to this portion of their argument, beginning on page 138 thereof, do not say anything in the paragraph relating to chlorine which has any reference to the Illinois River as a contributor of the chlorine to the waters of the Mississippi. It must be remembered that the Missouri River has the largest amount of chlorine, followed by the Illinois and that the Mississippi has the less amount. So, the fact that "the chlorine in the Missouri shore is higher than the chlorine at the Intake tower," as quoted by counsel simply demonstrates, to use their own words "that the water at the Intake tower is not altogether Missouri River water." It may be Missouri and Mississippi River water, but does that prove that Illinois River water is contained therein? Then counsel state "It is also shown that the chlorines at the Intake are higher than the chlorines in the water in the Mississippi above Grafton. It therefore becomes conclusive that the large quantity of chlorine entering at the Intake must come from the Illinois River, the Illinois River above Grafton containing a larger quantity than the Missouri or Mississippi." Reference is made to record, 1221-3, which does not sustain this position.

The fact is that there being more chlorine at the Intake than in the Mississippi above Grafton, shows that additional chlorine has entered the Mississippi, but whether it comes from the Missouri or Illinois is a matter of speculation, and therefore is no proof that any part of the Illinois River water passes at the Intake.

Defendants, however, conducted experiments along this line

to determine the commingling of the waters of the Illinois and Mississippi at Alton.

In regard to these experiments, Prof. Palmer testified as follows:

"With respect to the data included in the tables 51 to 62 inclusive, I may say that for several years samples of water were collected from the Illinois River at the intake of the old Alton city waterworks, and also a few samples were collected at mid-stream, but that in the fall of 1898, arrangements were made for the collection of a series of samples at a point opposite the new water works nearly a mile above the town. At this place five samples were collected at five different points across the stream for the purpose of determining the differences in composition due to the incomplete mingling of the waters of the Illinois River with those of the Mississippi River. The point at which these samples were taken was 16 to 17 miles below the mouth of the Illinois River at Grafton and six or seven miles above the mouth of the Missouri River or fifteen or sixteen miles above the intake of the St. Louis water works at the Chain of Rocks.

Consideration of the data of the tables shows how incomplete is the mixing of the waters of the Illinois with the waters of the Mississippi, the facts being brought especially by comparison of the proportions of chlorine contained in the waters of the Illinois River and the Mississippi River above Grafton with those found at different points in the cross section of the stream at Alton." (5445.)

"Plate No. XXVI. reproduced on page 5447 of record, gives comparative curves representing the results of chlorine determinations in the regular weekly samples collected throughout the years 1899 and 1900, the data appearing in detail in tables 53 to 62 inclusive. This plate shows graphically the amount of chlorine found in the Mississippi River at Alton in the years 1899 and 1900 from samples taken in

a cross section at five different points across the Mississippi River at Alton.

"In the latter part of the year 1900, as it was found necessary to contract the amount of work being done upon these waters the collection at one-fourth distance from the Missouri shore and at one-fourth distance from the Illinois shore, were discontinued and only three taken at the cross section points, namely: one near to the Illinois shore; one near to the Missouri shore, and one at a point midway between the two banks. (5448.)

"Comparisons of the lines representing the proportions of chlorine contained in the water of the Mississippi at Grafton and with the lines representing the proportions of the chlorine contained in the water of the Illinois at Grafton and with those representing the proportions of chlorine found in the incomplete mixture of Illinois River and Mississippi River waters at the different points at Alton, show that the water toward the Illinois shore was much more like the water of the Illinois River than it was like that of the Mississippi River above Grafton, with respect to the content of chlorine, and that the water of the Mississippi at Alton towards the Missouri shore was very much like that of the Mississippi above Grafton and very much more like that of the Mississippi above Grafton than like that of the Illinois." (5448.)

Testifying in regard to plates 27, 28 and 29, Prof. Palmer says:

"The quantities of water, that is the proportional quantities of Illinois River water and Mississippi River water have been calculated from the average content of chlorine for the year for each one of the five points in the cross section. They show that comparatively little of the water of the Illinois River reaches the Missouri side of the Mississippi at this point. For the year 1899 2.4 per cent of the water near the Missouri shore came from the Illinois River;

the other 97.6 per cent. consisting of water from the upper Mississippi at the point one-fourth the distance from the Missouri shore, the Illinois River water amounted to 4.8 per cent., while the Mississippi River water was 95.2 per cent. of the mixture; at the mid-stream, that is a point midway between the two banks the proportion of Illinois River water was 11.3 per cent.; that of the Mississippi, that is, the upper Mississippi River water was 88.7 per cent. At a point one-fourth distance from the Illinois shore, the Illinois River water amounted to 23.5 per cent., while the Mississippi River water amounted to 76.5 per cent. Near the Illinois shore the Illinois River water preponderated, amounting to 30 per cent. of the water passing down at that point; the Mississippi water constituting 62 per cent of the mixture.

For the year 1900, similar facts appear, except that there was a little more of the Illinois River water towards the Missouri shore, the percentage being 4 per cent. Illinois River water near the Missouri shore; 96 per cent Upper iMssissippi River water.

At one-fourth distance from the Missouri shore the Illinois River water constituted 10 per cent. of the mixture, while the Mississippi River water constituted 90 per cent. At mid-stream there was 13 per cent. of water from the Illinois River and 87 per cent. of water from the Upper Mississippi.

At one-fourth distance from the Illinois shore the mixture consisted of 40 per cent. Illinois River water and 60 per cent. water from the Upper Mississippi; while close to the Illinois shore, the mixture contained 46 per cent. of Illinois River water and 54 per cent. of water from the Upper Mississippi.

It is evident from the data of the tables 51 to 62 inclusive, and is expressed graphically by the figures and the lines of this plate, that the Illinois River water does not mix perfectly with the Mississippi River water, but passes down

mainly toward the Illinois shore or alongside the Illinois shore on its way down stream in the bed of the Mississippi River.

From certain analyses of samples of water taken in the Mississippi River about half a mile above the mouth of the Missouri River, it is my opinion that the mixing of the water of the Illinois with the water of the Mississippi is by no means complete by the time these bodies of water reach the mouth of the Missouri.

In my opinion there is no thoroughly satisfactory basis for a calculation of the relative proportions of Illinois River water, Mississippi River water and of Missouri River water, in the mixture which passes the intake tower of the St. Louis water works, but for such calculations the chlorine content would in all cases be the most satisfactory basis because the chlorine is not a variable constituent, or rather does not vary from causes which bring about variations of all other constituents which it is customary to determine in sanitary water anaylsis.

Q. Would it be practicable then to calculate the mixing of the waters of these three rivers from the proportions of total solids?

A. It might be; in case the proportions of total solids were sufficiently different in the three streams which were coming together, but even then there would be very great difficulties in the way of making a reasonable approximate calculation or a reasonable approximation of the true proportions, for the reason that the total solids include matters which are in suspension, and which by reason of variations in velocity of the stream, variations in the character of the material lying in the bottom of the stream and constituting the banks of the stream, which cause variations in the proportions of suspended matters even within short distances.

Q. What reliability could be placed upon a calculation

as to the mixing of the waters of these three rivers from the proportions of suspended matters?

A. That would be unsatisfactory for the reason just stated in referring to the possibility of calculating the mixing from the total solids, which total solids of course include the suspended matters. The different velocities at different times in the year and at different points even within short distances of each other, and the different character of the material with which the water is in contact, bring about in many cases a deposition of much of the suspended matters, forming as is well known, sand bars and other deposits in the stream, and on the other hand, where the character of the banks or of deposits in the bed of the stream are such that they can be easily removed by water, oftentimes the water picks up and holds in suspension considerable quantities of foreign matters which it may derive not from tributaries at some distance, but from localities and deposits quite near to the point at which determinations are made. That is to say, there is no certainty and in this particular case there would be no certainty that the quantities of suspended matters found in the waters of the Illinois at Grafton would proceed down in the Mississippi River to the St. Louis water works. There is no certainty that the quantities of suspended matters contained in the waters of the Mississippi above the mouth of the Illinois would remain in those waters until such time as this body of water reaches the intake of the St. Louis water works, and there is no certainty that such suspended matters as are contained in the waters of the Missouri River above its junction with the Mississippi remain in that water until such time as it reaches the intake tower of the St. Louis water works; for these reasons: Calculations based upon the suspended solids and upon the total solids which include suspended solids have no sound basis in fact, and on the other hand, at times the body of water passing down the bed of the Mississippi above the mouth of the Missouri may

between the mouth of the Illinois and the mouth of the Missouri pick up and hold in suspension matters which would then be in excess of the quantities found in the waters of the Illinois and of the Mississippi at and above Grafton, and likewise the mixture of the three bodies of water between the mouth of the Missouri River and the intake tower of the St. Louis water works, may in this stretch of six or seven miles,—perhaps eight or nine miles, pick up from the sand bars and the banks of the river, suspended matters which were not contained at this time, at least in the waters of either the Missouri or the Illinois or the Mississippi.

Hence, in my opinion, it is totally impracticable to calculate the relative proportions of water from these sources contained in the mixture passing down the Mississippi River beside the intake tower of the St. Louis water works." (5457.)

Prof. Palmer further said:

"Defendants' Special Cross-section Sheet No. 3, containing data of the analyses of cross section samples collected in the Mississippi River at Hartford half a mile above the mouth of the Missouri River, which samples were collected December 6, 1899, and July 7, 1900, and August 17, 1900, show that the waters of the Mississippi River have not commingled perfectly with the waters of the Illinois River by the time these two bodies of water have reached this point where they are about to come in contact with the waters of the Missouri River, and show that even down to this point the waters of the Illinois River pass down mainly along the Illinois shore, while the water passing down near to the Missouri shore is mainly the water of the Upper Mississippi River.

The cross section of the Mississippi River taken two miles below the mouth of the Missouri River merely affords evidence of the incomplete commingling of the three bodies of water at this point, and is corroborative of the more extensive

series of cross section analyses which have heretofore been testified to." (5524.)

Prof. Palmer also testified:

"I have prepared plates graphically illustrating the detailed examinations contained in these tables.

Plate No. 101, series 1901, A. W. P., represents the averages for the period of three months, October, November and December, 1901, and those for the same three months in 1899 in parallel columns.

The comparison of the three rivers, the Missouri, the Mississippi and the Illinois, exhibits a very great difference between the Illinois and the Missouri on one hand and the Mississippi on the other, during the periods in question.

This plate represents the average proportions of chlorine in the waters of the Illinois River at Grafton, the Mississippi River at Grafton above the mouth of the Illinois, the Missouri River at Fort Bellefontaine and at four points in a cross section at the Chain of Rocks, for the months of October, November and December, 1899, and for the same months in 1901.

The comparison of the three rivers, that is the Illinois just above its mouth at Grafton, the Mississippi just above the mouth of the Illinois at Grafton and the Missouri River at Fort Bellefontaine, exhibit a very great difference between the Illinois and the Missouri on the one hand and the Mississippi on the other, during the periods in question.

The content of chlorine in the Mississippi is practically the same as in the earlier year, the same in 1901 as in the earlier years.

The content of chlorine in the Mississippi River water was about the same as in the Illinois River. The greater dilution in 1901 has of course manifested itself in somewhat lower chlorine than in the year 1899.

The significance of these features is determined upon the fact that we have demonstrated elsewhere that the water of the Illinois River does not mix perfectly with the water of the Mississippi on its way from Grafton down to the Chain of Rocks, and that the Illinois River water flows mainly close to the Illinois shore, while the water near the Missouri shore consists mainly of Mississippi River water, mixed only slightly with Illinois River water, though at mid-channel there is more or less considerable mixing of the waters of the two streams. That these conditions prevail down to the mouth of the Missouri River, the Missouri River water as it enters the Mississippi deflects the Mississippi River water forcing it toward the Illinois shore, and it passes down chiefly toward the Missouri shore. It mixes of course to some extent with the fluid coming down from the Upper Mississippi at this point, but it is substantially but slightly mixed Mississippi River water, which is toward the Missouri shore; that is the main body of water from the Illinois River is toward the Illinois shore and it is water of the Mississippi River mixed with but small proportions of the water from the Illinois, which comes into immediate contact with the discharge from the Missouri River when the Missouri River water enters the bed of the Mississippi and it is quite unlikely that any considerable proportion of Illinois water mixes at first with the Missouri River water, but rather it is mainly Mississippi River water containing but a small proportion of the water of the Illinois River.

What we have then, briefly stated is, first, a body of Missouri River water passes down the west or Missouri bank; second, the mixture of Mississippi River water with Missouri River water containing but a very slight proportion of Illinois River water; third, Mississippi River water containing more Illinois River water in the middle; fourth, Mississippi River water mixed with a considerable proportion of the water of the Illinois River; fifth near the Illinois shore the

larger proportion of Illinois River water mixes of course with the Mississippi River water and to some extent also with the water of the Missouri River.

To be sure, there is no fixed line of demarkation between any of these mixtures, but the mixing takes place gradually, and we certainly have combinations such as I have indicated at the different points across stream. Water for samples taken at the Chain of Rocks shows that the water at the Illinois shore contains far less chlorine than does the Illinois River water pure and simple, but far more than does the Mississippi River water above Grafton. There has occurred a somewhat extensive mixing at mid-stream. We find water having almost the same content of chlorine as at the Illinois shore, while at the intake there is less chlorine than in the Missouri River water at Fort Bellefontaine and considerably less than at the Missouri shore. It is to be noted, however, that the collections at Fort Bellefontaine are not quite so numerous as those at the Chain of Rocks. They did not begin for some ten days or so after the time when those taken at the Chain of Rocks began.

The data of the analyses show, and it is evident from the relative heights of these columns that although the Missouri River water did not extend so far across the stream beyond the intake tower in 1901 as it did in 1899, yet there was no more Mississippi River water and there was no more Illinois River water in the mixture at the intake tower in 1901, that is, after the opening of the Chicago Main Drainage Channel, than there was in 1889." (5562.)

We submit that the foregoing tables showing the result of the examination made by defendant of the Mississippi River in a cross section, taking in five separate points from shore to shore in the Mississippi at Alton conclusively show that there is not a mixing of the waters of the Illinois and Mississippi Rivers at his point. This is not simply the opinion of

any witness but is a conclusive determination, the result of extended examinations made expressly for the purpose of establishing the real conditions as they exist at this point.

Counsel on page 139 of their argument refer to the tables made by Mr. Getz and from which deductions are made by Dr. Teichmann. This table we submit can have no force in determining the relative amount of Illinois or Mississippi water at the intake. In the first place this table is based on the amount of solids found in the waters of the two rivers. As shown by the testimony of Prof. Palmer, above referred to, it is not practicable to calculate the mixing of the waters at the intake from the proportion of solids or suspended matters found in the respective waters.

The tables copied in the argument of counsel were first introduced in evidence by the witness, William H. Getz. In addition to the reasons assigned by Prof. Palmer this table cannot be relied on for the reason that the volume of water in the Mississippi River as compared with the Missouri River is not taken into consideration. In explaining this table this witness states on page 1973 of the record as follows:

"When I made these figures as to solids, I took them from the Missouri River at Bellefontaine and for the Mississippi at Hartford. I made the calculation for total solids. There is always considerable variation in the total solids as found in the Missouri River at Bellefontaine, and those found in the Mississippi at Hartford, and the total solids at the intake of the St. Louis water works was found to lie between those two, or approximately the same as either one of them, and by taking the difference in the total solids in the two rivers at those places, and the interpolating the value of the total solids found at the intake, we find the percentage of the two rivers, which is represented by the mixture."

Witness admits that rainfall, floods and so forth, would affect the result. (1976.)

By the cross sections taken by Prof. Palmer we can follow the water of the Illinois River as it flows into the Mississippi and we show by these cross sections that the Illinois River water does not commingle with the Mississippi but hugs the Illinois shore as it flows down the Mississippi River. It will be perceived that there is no difficulty in the way of making such an experiment. In the explanation made by Mr. Getz, however, of table made use of by counsel in their argument, this witness states that because there was 800 parts of suspended matter or solids per million in the Missouri River at Bellefontaine, 500 at Hartford in the Mississippi River, and 720 at the intake, that therefore the water at the intake was composed of 73 per cent. of Missouri River water and 27 per cent. of Mississippi River water. This statement he makes without taking into consideration whether there was one cubic foot of water flowing per minute in the Missouri or one million in the Mississippi River on the same day. Besides, he refers to one sample taken at Hartford as indicative of the amount of suspended matter in the entire Mississippi River at that point. We have shown by the cross sections above referred to that the water shows a different determination at each of the points in the cross sections taken by defendants, and for this reason alone the table should not be considered.

If, however, it be admitted for the sake of argument, that the method followed by this table in determining the mixture at the intake is correct then this table only shows the relative amount of Mississippi and Missouri River water at the intake. As the Illinois River forms but a part however of the mixture in Mississippi River between Grafton and Hartford this table fails entirely to show what part of the 73 per cent. above referred to, for instance, is Illinois River water. As we have shown above by the cross section examinations made by Prof. Palmer that the Illinois River hugs the Illinois shore unless the sample was taken on the Illinois shore it fails

to show anything so far as the Illinois River is concerned. In fact, our cross section examinations show conclusively that at five different points in the river five different results were obtained. If the sample made use of in the table was taken from the center of the river then it does not indicate any Illinois River water was present at the intake and shows conclusively that the 73 per cent. referred to must be entirely Mississippi River water. Of what benefit then is a table of this character if it fails to take into consideration the relative volume of the streams in question? Had complainant proven that there was an absolute mixing of the Illinois River water with that of the Mississippi at the point where the sample was taken at Hartford and were it also shown that the method employed was the correct one and that the volume of the streams was taken into consideration the table referred to might be taken as fairly indicative of actual conditions, but we submit that the experiments made by defendants in taking cross section samples of the Mississippi River above the mouth of the Missouri robs the table used in argument by counsel of any value it might have in determining the mixing of the waters at the intake.

Defendants realized the inaccuracy of any determination that was not based on the flow of the streams in question. John W. Hill was called by defendants and testified on page 542, as follows:

"Q. If the Illinois River discloses a less amount of impurities than the Missouri what would be the effect of the water of the Illinois emptying into the Mississippi River at Grafton and subsequently uniting with the Missouri at its mouth upon the combined waters of the Mississippi and Missouri Rivers at the intake tower at the Chain of Rocks?

A. Considering the relatively small natural stream flow from the water shed of the Illinois River when compared with the stream flow of the Mississippi River above St. Louis and

the stream flow of the Missouri River, and ignoring or setting aside the fact of the water of the Illinois River being either better or worse than that of the larger streams the addition of the ordinary stream flow from the Illinois River to the combined stream flow of the other two rivers would not have much effect either way. In order to reduce this to a more definite statement I have prepared a table showing the relative areas of the drainage basins of the three rivers mentioned in the question, and assuming for the present that the mean rainfall would be the same over the combined drainage area of the Illinois, Mississippi and Missouri Rivers upon this basis, and omitting all flow of Chicago sewage or of water from Lake Michigan, of each 100 gallons of water flowing in the Mississippi River opposite the Chain of Rocks, 75 1-4 would come from the Missouri River water shed, 20 1-3 from the Mississippi River water shed and the remaining 4 4-10 from the Illinois water shed.

"As a matter of fact, however, the mean rainfall over the whole area of the Missouri River watershed is not so great as that over the watershed of the Illinois and of the Mississippi Rivers and it is probable that of the total flow of water in the Mississippi River opposite St. Louis, 70 per cent. can be charged or credited to the Missouri River watershed; 20 or 22 per cent. to the Mississippi watershed and the remaining 6 or 7 per cent. to the Illinois River watershed. In this case it is assumed that no water falls in the Illinois River except that due to the rainfall on its drainage basin.

Q. Have you figured out the results, adding the flow from the Drainage Canal?

A. I have upon the assumption only that the mean annual rainfall is substantially uniform over the entire Mississippi River basin embraced in the watershed of the Illinois and Mississippi Rivers above St. Louis and the Missouri River which is not as stated in the answer to the previous question.

quite true, but for this purpose may be accepted as true. Allowing the last stream flow of the Illinois River at Grafton as reported by the United States Engineers in October, 1891, of 1,000 cubic feet per second and assuming the discharge from Lake Michigan through the Drainage Canal of 300,000 cubic feet per minute or 5,000 cubic feet per second and allowing for the discharge of sewage based upon 90 per cent. of 85 per cent. of the total water consumption of Chicago which produces a discharge of 424 cubic feet per second, the percentage of volume of flow with the least recorded stream of the Illinois River at Grafton would be seven (7). Taking this flow into consideration and also taking into consideration the flow of sewage from Chicago plus the flow from Lake Michigan. Of the water flowing in the Mississippi River opposite St. Louis, 20 per cent. would be credited to the Mississippi River, 75 1-2 per cent. to the Missouri River and *2.96 per cent. to the Illinois River, and 1.54 to the influence* of the discharge of the *Chicago sewage*, or such water as is carried with the sewage into the Drainage Canal exclusive of the diluting water drawn from the lake."

Prof. Jordan testifies that whatever mixing of the Illinois River water does take place at the intake is beneficial to the water supply of St. Louis. He says:

"The colon content of the Missouri River is markedly higher than that of either the Illinois or the Mississippi River at Grafton, and from this I infer that during this period the Missouri River was more highly charged with dangerous bacteria and was distinctly less safe than the waters of the Illinois River.

Under these conditions the effect of any mixture of the Illinois River water with the Missouri River water at the intake tower of the St. Louis water works, would therefore tend to diminish the colon content of the water at that point, thereby rendering it less dangerous for the human use. Such

mixing of the Illinois and Missouri waters as took place would hence improve the conditions existing during this period in the Mississippi River at the intake tower." (6132.)

15.

MOST CONCLUSIVE EVIDENCE OF THE SANITARY QUALITY OF THE WATER SUPPLY.

The burden of complainant's argument under this head (page 146) is to the effect that chemistry and bacteriology are not necessary for the determination of the sanitary quality of a water supply, but it will be noted that under this head no authority is cited by counsel other than Gardner Stewart Williams. On page 47 of complainant's argument, in stating the qualifications of this witness, counsel say:

"Mr. Williams lives at Ithaca, New York, his present occupation being that of consulting water supply and hydraulic engineer, and professor of experimental hydraulics in Cornell University, having been connected with Cornell University in above capacity since 1898."

So, this witness is neither a chemist nor a bacteriologist. If the Court will read further in the statement of counsel as to the qualifications of his witness it will find that Mr. Williams' occupation for a good many years was the designing and constructing of engineering work in connection with water supplies. As professor of experimental hydraulics in Cornell University, this witness states, on page 4419 of the record, that his duties consist in supervising extensive experiments on the flow of water in open channels and over dams, etc.

It is only natural that a witness called as an expert should state that the matters of which he has no knowledge, or a branch of learning with which he is not familiar, are not necessary for a determination of the issue presented to him.

We agree that chemical analysis fails to disclose disease producing organisms, in water. There was no effort made by defendants to depend entirely on chemical analysis or bacteriological examinations alone, but the evidence will disclose to the Court that use has been made of the combined results of chemistry, bacteriology, sanitary engineering and bacteriochemic examinations.

Complainant well knew that this was the proper method of examining water for the purpose of ascertaining its sanitary character when they started taking evidence in this case. Having taken the testimony of the bacteriological and chemical experts and having failed to make a case by their own evidence they refer in their argument to the testimony of a single witness whom they called upon after their scientific testimony was in; this witness stating that it is not necessary for an "expert" to "depend upon or require either a chemical, microscopical or bacteriological analysis of water to determine its pollution." These words came from a so-called, epidemiologist. This is the same witness who "discovered" the Detroit Epidemic which we have heretofore referred to. (It will be remembered that he came to the conclusion that typhoid fever in Detroit was caused by the dredging of the Harbor of Port Huron, although he admitted he did not know whether there was any typhoid fever at Port Huron during the time of the dredging, and it became necessary for complainant to introduce testimony to the effect that typhoid fever did exist at the time.)

Mr. Allen Hazen is another so-called epidemiologist whose real occupation is that of civil engineering and who testifies on page 2084 of the record that a large part of his business is that of constructing filter plants. This witness is neither a bacteriologist nor chemist. He states that he wrote a paper in 1892 in connection with Prof. Sedgwick also a witness for complainant in this case, as to the conditions of typhoid in

the City of Chicago in 1892. That their conclusion at that time was to the effect that the cause of typhoid in the City of Chicago resulted from the sewage that entered Lake Michigan, and then into the water supply of the city. (2285 and 2816.)

Prof. Long, a chemist, in testifying about the epidemic that Mr. Hazen attributed to the sewage of Chicago entering Lake Michigan and polluting the water supply said:

"Q. Now, professor, I understood you to say that you, in making your chemical analyses and giving your opinion upon the sanitary condition of the water of the Illinois River, you disregarded the opinion of epidemiologists and those sanitary experts who recognize an association between the pollution in water and disease germs and diseases which are brought upon people who are in the habit of drinking the water?

A. In forming my conclusion, or in stating my conclusions, I will say that I have not attached much importance to the opinions of epidemiologists, but I have in the reports which have been published referred to the work of others who have made parallel investigations and who will testify when the time comes, whose investigations were made parallel with my own, and on the same waters in most instances.

Q. You have never investigated the relations of health and water here at Chicago or anywhere else, have you, professor?

A. Not in a very extended way, but far enough to show that the assumptions made by certain epidemiologists who claim that they have made studies of the water supply of Chicago at several periods in the history of Chicago, but not founded on sufficient knowledge of the facts to merit the attention which the publications really attracted.

Q. Now, professor, will you state the reason why you have thus concluded?

A. I stated yesterday in some detail, one of the main reasons for my lack of faith in the opinions advanced by these infant industry scientists called epidemiologists. It is well known that in drawing their conclusions these people have been so often ignorant of the most important facts in the case, that the conclusions are finally of no value. From my own studies, and investigations, and from my knowledge of things as a citizen of Chicago,—things which I have paid close attention to for over twenty years, I am able to state positively that in several of the most noted of these cases where epidemiologists from abroad have passed on the condition of affairs in Chicago, they were certainly mistaken in their conclusions. For instance during the World's Fair, when a good deal was said about the infection of Lake Michigan water, a good part of the supply in one section of the city was drawn not as was supposed—from the Chicago Avenue tunnel, extending out about two miles, but from a short, or emergency inlet—a short tunnel extending out to a distance of about 500 feet, to be used in case of emergencies, in case of a large fire for example. At that time the pumps which were at work in the pumping station at Chicago Avenue, were generally in pretty poor condition. There was frequent complaints of the amount of water which they could pump. There was very frequent complaint of lack of sufficient head to carry the water above the first or second stories of the buildings. At that time in order to lessen these complaints it has been established by investigations, as will be explained, that water was drawn by the engineer in a large quantity and through a very considerable period from the short inlet. This water was very dirty. It was drawn from a point where there was considerable contamination from dumpings and washings and sewers and so on. Therefore I say that the conclusion that the water from the two-mile tunnel was the source of the disease which the epidemiologists described at that time, is not a fair conclusion. At a later period, last

year, through the spring and summer of last year, there was a remarkable epidemic of typhoid fever in Chicago. It was a very singular fact—a puzzling fact, that the greatest prevalence of this appeared to be in a part of the city which received what was supposedly the purest water drawn from the longer tunnel, and a great deal was written and expressed in public addresses, in regard to the infection of the water at that great distance, shown from the appearance of fever in this part of the city. It was later discovered, some time in June, I believe, that through some accident or oversight which occurred many years ago,—how many we cannot say definitely,—perhaps over ten or fourteen years— certainly at a period beyond the recollection of the men employed in the pumping station, a connection was left between a well in the pumping station and a sewer, so that at the time of high water, at the time of heavy rains, it was possible for one of the large sewers in that part of the city to flush over and throw a great volume of foul water through a ten inch pipe into this well, so that it could be drawn into the supply. That fact is known to many people in the city and in the engineer's office. I state that here then as a further explanation of why I am not willing to accept the determinations of the etiologists and epidemiologists. I am referring principally to people in Chicago who made these complaints of last year, that the source of the infection must be referred to Lake Michigan. It is evident that that was not the source of the pollution in the mains in that part of the city. Those are two, and I think, sufficient illustrations for all practical purposes." (4298, *et seq.*)

This shows that the theoretical conclusions of epidemiologists cannot be relied on.

Mr. Williams, the only witness quoted by complainant to sustain its position in this part of the argument also states that "an expert in determining the quality of water supply

avails himself of *all* the information which he can possibly obtain concerning that supply," and further adds that "a chemical analysis is a valuable aid in that it may show the presence of substances which would be inimical to the health of persons using the water." (2463-4.)

On page 2465 of the record this witness states that his reason for holding to the view that the failure to appear in a chemical analysis of water on the part of any or all of those substances which are recognized as connected with pol lution is not to be taken as an evidence of purity, is that the infectious quality of the water is dependent not upon its chemical constituents, but upon the presence therein, generally speaking, of living organs which are of such minute character and may be so few in number that they are entirely beyond the range of chemical analysis to detect and yet may be there in sufficient quantities to cause very serious results in the event of such water being used for drinking purposes. (2465.) This is the testimony quoted by complainant on page 147 of argument.

Witness then refers to the River Dee, stating that while the chemical analyses was entirely unable to detect the presence of microbes that the bacteriological examination showed the bacterial content of the water to contain thousands of organisms on a cubic centimeter. (2465.) There is nothing remarkable about this statement for it was never contended by anybody that the number of bacteria per cubic centimeter could be determined by a chemical examination. No such preposterous experiment has even been attempted by the defendants. In this record is contained *chemical analyses* made by witness for the defendants to show the *chemical* condition of the various waters at the places where samples were taken.

For the determination of the number of *bacteria* present and the kinds of bacteria, resort has always been had to

bacteriology. It will therefore be seen that by reference to that part of the testimony of this witness which has not been quoted by counsel, that this witness admits that although chemical examination may not disclose infection a bacteriological examination will. While this witness states on one page that "it is not necessary for the expert to depend or require either a chemical or microscopical or bacteriological analysis of water to determine its pollution" on the very next page he states that the chemical analysis is one of the aids that water experts use in determining the quality of water supply. There might be some force in the statement of witness that a bacteriological examination was necessary, had no bacterial examinations been made by the defendant. But, considering the fact that both chemical and bacterial examinations have been made by defendants and introduced in evidence from the year 1886 till the proofs were closed in this case we fail to perceive the materiality of the statements contained on pages 147 and 148 of counsel's argument.

This witness however has taken the most unique positions in regard to certain elements relating to the controversy in this case, and has gone further than any witness called by either side. On the very page in which the statements quoted by counsel in the argument are made this witness states that diptheria is a water borne disease. This is the only instance in the literature or in the record in this case in which can be found that statement. On cross-examination, this witness also made a statement as follows:

"Q. Assuming that there should be typhoid fever in New Orleans, and two months before one case of typhoid fever appeared upon a steamer in Lake Itasca, the source of the Mississippi River, and there were no other cases of typhoid fever between that point and New Orleans, and no other source of infection, would you attribute the case in New Orleans to the case in Lake Itasca?

A. I am afraid I would have to. These things do not generate of themselves."

How much this witness knows and how little is necessary for him to base a conclusion on is shown in his cross-examination beginning on page 2551 of the record.

"Q. Are there other persons, sanitary engineers, expert in water supplies in this country, who are as familiar with the subject as yourself?

A. I think there are not very many.

Q. About how many?

A. At the present moment I do not think of any whose judgment I would take in preference to my own, or whose judgment I would advise a client to take in preference to my own." (2546.)

"Q. Well, nobody knows any more about this subject than you do, do they?

A. Well, I don't think that anybody knows very much more." (2575.)

Prof. Long states that he considers both the chemical and the bacterio-chemic tests of importance in the determination of the pollution of the water supply, and this witness on page 4271 of the record states, on cross-examination, that in addition to the bacterial and chemical elements combined, "It is always desirable of course in drawing a conclusion from such examinations, chemically and bacteriologically, to have as much knowledge as possible of all the conditions that obtain in any stream in question,—all possible factors should be taken into consideration in reaching a conclusion."

He also says:

"Q. Professor, are all pollutions equally dangerous?

A. No, in general it would be safe to say not.

Q. Of what benefit then is the chemical analysis of the

water which you have examined, and which is represented by the tables which you have introduced in evidence here, in deriving knowledge as to the sanitary condition—or information as to the sanitary condition of the water?

A. Well, this chemical knowledge, combined with the knowledge of the origin and sources of the waters in question, permits a comparison to be made between the different waters as to the amount of their pollution. The work is of comparative value.

Q. Then, as a chemist, any conclusions as to the sanitary condition of the water from the chemical analyses that were introduced by the tables here, would be unreliable, would it not, so far as infection is concerned?

A. That does not follow, because we must call upon our practical knowledge and practical experience regarding the sources of water, as we know that infection in the general sense of the term cannot and does not take place in water except by the addition of something else, which the chemist can recognize and does recognize. These tables then have some value in measuring the relative danger or the relative safety of water." (4289.)

Prof. Palmer, a chemist, on cross-examination, testifies as follows:

Q. Is it your opinion that you can ascertain the sanitary condition of the water from the analyses which you have made of the various rivers tributary to the Illinois River, and the Illinois River, and that you can obtain and have obtained accurately the sanitary condition of that water and ascertained as to whether or not the waters of those rivers contained deleterious matters or disease producing elements or organisms?

A. It is my opinion that the analyses which I have made of the waters of the streams of Illinois and to which I have testified in this case throw much light upon the sanitary con-

dition of the waters in these streams but do not directly determine the question as to the presence or absence of disease producing organisms in said waters.

Q. Then you do not say that in these determinations you have ascertained the presence or non-presence at any time of disease producing elements or organisms?

A. I say that in my opinion I have not by my chemical investigations of these waters determined the presence or absence of disease producing organisms. I do not quite understand the meaning which you attach to the term disease producing elements.

Q. The word "elements" for the information of the witness, is used for the purpose of giving the question the broadest possible significance for sanitary purposes.

A. I still fail to discover any precise meaning attached to the word "element" in this question.

Q. State professor, whether or not in your analyses of the waters contained in the Chicago Drainage Canal at Lockport, or at any other place, you obtained the presence or non-presence of disease producing organisms or substances or evidence of their presence in that water?

A. My sanitary chemical analyses of the waters of the Illinois and Michigan Canal, and of the Chicago main drainage channel were not such as might be expected to determine directly the presence or absence of disease producing organisms, but inasmuch as they were of such a character as to show the presence or absence of sewage, they do indicate the possible presence or absence of substances characteristic of sewage and hence, in some measure, disclose the presence or absence of deleterious substances, substances which as a class are objectionable in drinking waters, for the reason that they themselves or substances which accompany them in sewage,

are deleterious to health when introduced into the system through drink.

Q. Do you know professor, and is there anything in the science of chemistry as applied to sanitation which will give you definite information as to the presence, kind and characteristics of the disease producing organisms or substances which as stated in your last answer, accompany certain chemical constituents found in water?

A. It is my opinion that the basis for the detection of the presence and the kind and the characteristics of the disease producing organisms and substances which in sewage and waters at times accompany the chemical constituents found in these fluids, rests mainly upon the various chemical reactions and decompositions which said organisms and substances produce and the chemical substances which result from their action.

Q. Then by your answer, professor, do I understand you to say that from the chemical analyses of the water in the Illinois River and the Chicago Drainage Canal, that you can determine and have determined the presence, the kinds and the characteristics of disease producing organisms, which accompany certain chemical constituents found in those waters?

A. No; that is not what I understood and I do not wish you to understand me to say that.

Q. Then referring to my second preceding question, state if it is not a fact that you cannot determine from your chemical analyses made of the waters of the Illinois River and from the Chicago Drainage Canal and from those chemical analyses, you have not determined the presence, kind and characteristics of disease producing substances which accompany certain chemical constituents referred to by you in the preceding answer?

A. The sanitary chemical analyses which I have made of

these waters do not directly indicate the presence or absence of disease producing substances, and I have not determined directly the presence or absence of said disease producing substances in these waters.

Q. Is there anything in chemistry so far as you know, which recognizes certain disease producing organisms in water as applied to running streams?

A. In my opinion without the science of chemistry, or without a recognition of the chemical changes or the significance of the chemical changes which disease producing organisms bring about, there would be no means of determining their presence or absence in running water, but, the branch of science which is directly concerned in the utilization of chemical and other reactions for the purpose of determining the presence or absence of disease producing germs, is, in my opinion, the science of bacteriology." (5647-6-7.)

Prof. Jordan, testified as follows:

"Q. What is your opinion as to the value to be placed upn chemical and bacterial analyses of a water course?

A. It is my opinion that such analyses furnish important evidence as to the character of a water, and that while they often supplement and confirm the results of observation, they also at times reveal conditions that mere ocular inspection or observation would fail to bring to light.

Q. Do chemistry and bacteriology afford any assistance to an epidemiologist or a sanitarian in arriving at a correct judgment to be placed upon the value of a river water, and do they supply facts that are important?

A. In my opinion chemistry and bacteriology often afford very great assistance in arriving at a judgment of the character of a river water. It is sometimes true that chemical and bacteriological data are the only data that one can obtain in regard to the character of a given water and while the

inference from bacteriological or chemical data alone are perhaps rarely final, such data are frequently the only available material upon which a judgment can be founded.

In any case an experienced epidemiologist would attempt to secure chemical and bacteriological data regarding the character of a river water as constituting an important element in enabling him to form a judgment of the water." (6266-7.)

Prof. Jordan also said:

"Q. State in detail what position the science of bacteriology occupies in regard to the ascertainment of the purity of river waters?

A. In my opinion bacteriology affords a very valuable service to the sanitarian engaged in the consideration of the character of waters. The colon test represents, in my opinion, the most satisfactory single test for determining the wholesomeness of natural water. The information derived from this and other bacteriological tests should, however, be supplemented by chemical, epidemiological and other data where these can be ascertained.

Q. What position does the science of bacteriology occupy in what is known as sanitary science?

A. Bacteriology constitutes in a sense the foundation and basis of all sanitary science the infectious diseases with which sanitary science is particularly concerned are germ diseases. The best known of these germ diseases are due to bacteria of various kinds, and not only the nature of the infecting organism, but the vehicle of infection, the channel of entrance into the body and other factors depend for their distinction upon bacteriological data.

Q. State in detail what place the science of chemistry holds in regard to the ascertainment of the purity of river waters?

A. The data derived from the chemical analyses of river water are often very important in enabling a sanitarian to form an independent judgment as to the character of a water. The various stages of organic nitrogenous matter, the amount of chlorine and other elements furnish oftentimes a very good indication of the changes that have taken place in polluted river waters, and from this as a basis correct inferences can be drawn as to the degree of self-purification that has occurred.

Q. What position does chemistry occupy in what is known as sanitary science?

A. In addition to supplementing the bacteriological examination of river water the study of chemistry affords data that sheds light upon many of the general problems of sanitary science. In general, applications to the problems of bacteriology chemistry has been found particularly useful and important.

Q. In the ascertainment of the quality of river water what aid is chemistry and bacteriology to the sanitarian in forming a judgment of the quality and potability of such water?

A. The data derived from bacteriology and chemistry are often the only data that a sanitarian has for forming a judgment as to the character of a given water. Correctly interpreted these data afford very valuable and significant clues as to the sanitary history of a water and often to its quality at the time the examination is made. For a full and complete understanding of the character of a water such chemical and bacterological examinations are indispensable." (6328-9.)

Prof. E. G. Smith, testified:

"Q. State in detail what position the science of bacteriology occupies in regard to the ascertainment of the purity of the river waters?

A. The development of the study of the purity of river

waters requires a knowledge of the science of bacteriology, especially in relation to the presence or absence of sewage. The history of the science of the purification of waters shows that at first the clearness of the water was all that was sought after selecting and adapting a water supply. Later, the science of chemistry was applied to determine the purity of water, and since about '85, the science of bacteriology was developed, and has been applied to its study, so that to-day a satisfactory opinion upon the healthfulness or unhealthfulness of the water supply cannot be passed without a knowledge covering its bacterial contents. The study of the bacteriology of water has to do with the organisms present, and especially with the presence or absence of the colon forms, and forms like it. To-day, what interests in the study of the river water from its sanitary standpoint, is whether or not that river contains sewage.

It is commonly accepted at the present time, that diseases are caused by certain specific organisms, known as bacteria which can be borne by water, those of typhoid fever and of cholera are the most prominent. These are intestinal diseases, and, therefore, it is very important to determine whether or not fecal matters find access to the waters; we can use, therefore, the presence or absence of the intestinal bacteria as the most important index in determining the purity or impurity of the supply.

Q. What position does the science of bacteriology occupy in what is known as sanitary science?

A. The word sanitary science is a larger term,—sanitary science embraces primarily a study of the conditions of good health, and the study of foods, air and water.

I have already outlined the importance of the science of bacteriology in ascertaining the purity of river water. The science of bacteriology also occupies an important place in

determining the purity, or demonstrating the quality of food supplies.

It would be self-evident that if food became exposed to impure water, the food will be rendered unsafe and unfit for use; therefore, bacteriological study is an important factor in determining the characteristics of foods.

Q. State in detail what place the science of chemistry holds in regard to the ascertainment of the purity of the river waters?

A. The science of chemistry as applied to river water, has to do with the determination of the presence or absence of organic matters in the water. It is necessary that we should know the chemical constituents of water, from a sanitary standpoint, and whether it contains organic matter or not; it may or may not be possible to determine the bacterial forms present in the water, but we can determine the presence or absence of organic matters.

The relation of chemical science to the study of the purity of waters, has to do with determining whether organic matters are present or absent. Another province of the application of chemistry to the study of waters, is to determine what changes those organic matters added to the water undergo, after a period of time, so that we have the definite work of chemistry in determining the presence or absence of organic matters, and secondly, the changes which such organic matters may undergo.

Q. Does chemistry occupy an important position in sanitary science?

A. It is fundamental to the proper study of foods, of air, the nature of the food stuffs, and the nature of the water supplies the three great necessities of life.

Q. In the ascertainment of the quality of the river water what aid is chemistry and bacteriology to the sanitarian in

forming judgment as to the quality and potability of such water?

A. In my opinion the sanitarian could hardly form a proper opinion regarding the quality of a river water did he not have the chemical and bacterological data upon which to base such an opinion. As, for example, the Platte River, in Denver, is a bright clear stream coming down from spring waters out of the parks, up on the mountains. It is bright and clear, colorless and sparkling, pushing down over rocks, and no one would hesitate to drink that water. To look at it you would say that the water was entirely satisfactory, an ideal water, but when the bacteriologist comes to examine that water, he finds that it contains, and carries fecal matters. When the chemist comes to examine it he finds also that there is evidence of sewage borne in the waters, but the bacteriologist's services would be of the greater use there. The water, to look at would be seemingly perfectly satisfactory, but upon applying these several tests, it becomes evident at once that means of purification must be employed before the same can be delivered with safety to consumers.

No man could pass as a sanitary expert who did not seek, in passing upon the quality of a supply, to avail himself of all information possible, chemical, bacteriological, and knowledge of the sources of a supply and all sources of pollution to which it was exposed." (6771-2-3.)

Prof. Ravold, witness for complainant, says:

"Q. Is there any means now known of obtaining absolute proof of the hygenic quality of water supply?

A. Well, bacteriology will indicate the presence or absence of bacteria.

Q. Is that sufficient to determine the potability of the water supply itself?

A. Yes, sir, it was used by the German Government." (890.)

Prof. Sedgwick, witness for complainant, says:

"Q. If the Missouri River as you have heard of it and know it, was at its ordinary statge, would you consider that water dangerous?

A. I don't know whether I should or not, I should have to think that over. There comes a time in all questions of this kind when it is a very difficult matter to decide, and I don't know just where I should draw the line between water that I should drink with a gallon of sewage, and water I should not. I should want chemical and bacterial analyses of the water and I should want to know the conditions more than I now do,—the conditions of purification, en route, and a lot of things which are not included in that question." (2266.)

Prof. Zeit, says:

"I believe modern sanitation owes its advance mainly to the advances of bacteriology. Modern epidemiology and sanitary science has been entirely changed, as we have learned to know the etiology of infectious diseases, and their spread, so the modern sanitarian makes a specialty of applying that which we have learned from chemistry and bacteriology, and associated branches in the study of infectious diseases, as well as their prevention.

Q. What advantage if any, have the modern investigations by bacteriologists afforded to sanitation?

A. They have studied morphology and biology of bacteria, the etiology of disease, and determined in a great many of the infectious diseases the actual cause of the disease as well as the means of destroying that cause, and the modern bacteriologist bears about the same relation to the sanitarian, as the anatomist and physiologist or the chemist or the pathologist or the bacteriologist bears to the physician. The physician bases his knowledge upon the accumulated achievements of these other branches, and for the physician to deny the achivements of pathology or bacteriology or anatomy or chemistry

would have about the same significance as for the sanitarian to deny the achievements of the science of bacteriology in modern sanitary science. The whole knowledge of disease and the treatment of disease, has been entirely changed since the days of bacteriology, and we may well say that modern medicine owes its greatest triumphs and advancement to bacteriology. When we know the cause of the disease, we can usually also destroy it or avoid it, or prevent it, and I think the bacteriologist has the right to claim, that this science has given to the medical man as well as to the sanitarian, the proofs of the factors which cause most of the infectious diseases. That is true in most of the infectious diseases. Not all of them have been determined yet. And I think just as soon as they are discovered by the bacteriologist, that the sanitarian will make use of it, just as he does now of other facts which have been brought out by the bacteriologist, and which he simply applies on a large scale in the prevention of epidemics and the spread of infectious diseases.

Q. You stated yesterday that you had graduated at a medical college? A. Yes, sir.

Q. What year was that? A. 1887.

Q. About sixteen years ago? A. Seventeen years ago, yes.

Q. Since that time what effect has the increased knowledge of bacteriology had upon the science of medicine?

A. We have learned to know the causes of many infectious diseases; we have learned to prevent and to cure infectious diseases by the employment of substances which either destroy the germ itself, or will destroy its poisonous products, as for instance in the case of diphtheria anti-toxin and in the use of tenanus anti-toxins. We have learned that some of the diseases that were supposed to be due to the effluvia of swamps like malaria and so on, are really infections caused by micro-organisms which are carried from man to man by intermediate hosts, such as mosquitoes and the like." (4463.)

Prof. Kinnicutt, says:

"Q. State in detail what position the science of bacteriology occupies in regard to the ascertainment of the purity of river waters?

A. Bacteriology enables us to determine the number of bacteria in a water and to isolate and determine the number of certain species of bacteria. It enables us to tell indirectly something regarding the condition and amount of organic substances in a water and also to determine the vitality of certain species of bacteria. For studying the sanitary character of the water a knowledge of bacteriology is absolutely necessary.

Q. What position does chemistry occupy in what is known as sanitary science?

A. Chemistry tells us the amount of salts in the water, the amount and condition of the organic matter. It enables us to tell something regarding the past history of a water and indirectly gives us an idea as to the bacterial condition of the water. It also enables us to understand how the complex organic compounds such as occur in the food products and nature when placed in water are broken up, decomposed and gradually changed into gas and mineral substances.

Q. In the ascertainment of the quality of the river water what aid are chemistry and bacteriology to the sanitarian in forming a judgment of the quality and potability of water?

A. It is absolutely necessary to employ both chemistry and bacteriology, and it is impossible to form a correct judgment as to the quality and the potability of a water without the aid of both of these sciences.

Q. Does not a sanitary expert call to his assistance all the information available from chemical and bacterial sciences as well as knowledge of the source of pollution in passing judgment upon the sanitary character of a river?

A. In passing judgment on the sanitary character of a

river it is almost absolutely necessary to have a knowledge of the sources of pollution and a knowledge of the water shed. Without a knowledge of the nature of the water shed it is almost impossible to form a correct idea of chemistry and bacteriology alone, of the changes that are taking place in the river." (7456-7.)

If bacterial and chemical analyses are of no value, or "it is not necessary for the expert to depend or require either a chemical or microscopical or bacteriological analyses of water" why did claimant take thousands of samples and introduce thousands of pages of testimony showing the results of the bacteriological and chemical examinations made from such samples? Then, too, why do counsel devote their entire argument to a comparison of bacteriological and chemical conditions of the various streams under examination?

16.

"THE EFFECT OF THE OPENING OF THE CANAL IN CHICAGO UPON THE ST. LOUIS WATER SUPPLY."

The testimony quoted by complainant's counsel in their argument under this heading, beginning on page 148, consists of matter that is treated elsewhere in the argument and which is answered in this argument under various other headings. To avoid repetition we have deemed it advisable to simply refer the court to the headings "Typhoid Longevity," "Purification of Illinois River," etc., which answer directly every proposition presented by counsel for complainant under this head.

17.

"LONGEVITY OF BACILLUS TYPHOSUS OR TYPHOID BACILLI."

We concede, as stated by counsel on page 163 of their argument, that it is pertinent to the issues in this case to know just how long the typhoid bacillus will live in the water of the Chicago Drainage Canal, the Desplaines, the Illinois, and the Mississippi Rivers. We do not agree, however, that its longevity "according to all of the witnesses who testified in the case after many series of determinations is a matter yet unknown." We insist that the experiments conducted by the witnesses for the defendant prove conclusively the longevity of the typhoid bacillus in the waters in issue in this case.

Much space is devoted by counsel for complainant in setting out the results of the experiments made by Dr. Ravold. On pages 164 and 165 of counsel's argument, the number of days typhoid bacilli lived in distilled and sterilized water is given. The results there given are of no value to this Court in determining the longevity of a typhoid bacillus in the natural waters of the Drainage Canal and Illinois River. We do not find sterilized or distilled water in the Drainage Canal, but we find a sewage polluted water, which the record shows, causes a rapid destruction of pathogenic bacteria, owing to their over growth by the saprophytic bacteria. This point will be more fully discussed in another part of this argument.

On pages 166, 167 and 168 of complainant's argument, counsel refer to the results obtained by Dr. Ravold witness for complainant, in his experiments on natural water, that is, water taken from various points along the Drainage Canal, Illinois River, etc., which were inoculated by him with the bacillus typhosus and examined afterwards at certain periods to determine whether such typhoid bacillus were still alive.

These samples were either placed in an ice chest and kept at a low temperature during the investigation or hung in a window, where they were reached by the sun light during part of the day. These experiments show that in water from the Illinois and Michigan Canal at Lockport the typhoid bacillus live five days; In the Drainage Canal at Lockport, four days; In Illinois River above Peoria, five days; Illinois River, Pekin, four days; Chicago River, Adams Street, four days. (476.) The above were all samples exposed to the sun shine. In a sample from the tap in the laboratory in St. Louis June 13, 1901, exposed to direct sun shine all day, the typhoid bacillus lived twenty-four hours. (476.)

This witness then states that in the natural water in the Illinois and Michigan Canal at Lockport the average number of days that the typhoid bacillus were found alive was five—in the window exposed to the sunshine.

In the Drainage Canal at Lockport the average number of days was four and three-fourths days.

Chicago River, Adams street, four days.

From the tap in the laboratory at St. Louis, seven days. (477.)

Professor Whipple, a witness for complainant, in answer to the question, "Do you consider conditions in the laboratory, where experiments have been made, similar to conditions that exist in a running stream, sewage polluted," answered, "No, sir; I do not." (2081.)

Prof. E. G. Smith says:

"Q. Will the germ of typhoid fever live as long in polluted water as in pure sterilized water?

A. Experiments show they will not live as long in polluted water as in pure sterilized water. In fact, the longest period of life which we have observed in the case of the typhoid bacillus in experimental work, is where they have taken natural water and sterilized it.

Q. How do you account for this?

A. The organism, in a polluted water, is subject to certain enemies. It is subject to the toxins thrown off by the other forms and to the concentration of the toxins and to the varying conditions of the stream. If an organism be placed in polluted water, it will be subject especially to the destructive action of the type of the other organisms more than it is in natural drinking water." (Prof. E. G. Smith, 6752-3.)

Prof. John W. Hill says:

"A. I regard the laboratory test usually made, and certainly all that I have made or caused to be made, as more favorable to the growth of the typhoid organism than it would be in the normal water with which the experiment was being conducted, as the desire is to show the greatest possible longevity under the conditions of the test. This is brought about by maintaining a constant temperature of the flasks in which incubation is being carried on and by observing all other conditions conducive to the maintenance of life of the organism." (7517.)

Prof. Jordan says:

"Q. Are the conditions of laboratory experiments more or less favorable to the longevity of the typhoid bacillus than the conditions that obtain in nature?

A. In my opinion they are decidedly more favorable.

Q. Will you please state your reasons for that opinion?

A. It has been shown by experiments made by Ficker (Zeitschr F. Hyg. 1892, 29 P. 1) that water sterilized in glass bottles brings into solution substances which favor continued vitality on the part of the various micro-organisms. These experiments are well known and show how peculiarly favorable are the conditions in these glass bottle experiments for the long life of the microbes introduced.

Q. What reasons have you for the opinion that the life of

a typhoid bacillus in the waters of the Drainage Canal, the Desplaines and the Illinois Rivers is shorter as compared with the laboratory experiments?

A. In the water of the Desplaines and the Illinois Rivers the typhoid bacillus is subjected to the unrestricted action of the products of the various saprophytic microbes that inhabit these waters. The large amount of organic matter in the upper stretches of the river favors the concentration and the consequent intensity of action of these saprophytic products. As compared with the laboratory conditions again the typhoid bacillus can hardly be favored in these rivers by the presence of any substances as go into solution from the glass bottles used in laboratory tests. These two reasons, therefore, the absence of the favoring laboratory conditions and the free and vigorous action of the products of growth of saprophytic microbes lead me to adopt the opinion that I have just expressed. (6159-6160-1.)

Q. Are conditions of the laboratory experiments more or less favorable than conditions in nature for the longevity of the typhoid bacillus?

A. The laboratory conditions are more favorable for the longevity of the typhoid bacillus.

Q. If more favorable, state what reasons you have for your opinion?

A. The vessels in which the experiments are performed for some reason seem to give conditions favorable to its life, those vessels usually being small vessels of glass, but where the conditions resemble more closely those of nature, as for instance where a large tank is employed, the length of the life of the bacillus coli and of the bacillus of typhoid does not seem to be so great." (6911.)

Prof. Russell says:

"The conditions under which laboratory experiments have been performed on the longevity of the typhoid fever organ-

isms, are, as a rule more favorable for the prolongation of vitality of this organism, than would exist where the organism was exposed under natural conditions. It has been recognized by practically all investigators on this subject that the organism of typhoid fever lives longer in the sterilized water than it does under raw conditions and if such waters are polluted, if normal raw waters are polluted, it is my belief that the longevity of the germ would be much less in the case of purer sterilized water.

My opinion that the typhoid organism will not live as long in polluted as in pure waters which have been sterilized by heat, is based upon the fact that there exists an antagonism between the saprophytic bacteria, found in polluted waters, or the bi-products of the growth of these organisms and the typhoid organisms, which exerts a prejudicial effect upon the development of the typhoid germ, thereby diminishing its vitality and shortening its longevity."

"I think they would live longer in the sample in the laboratory experiment than they would in the running water." (Prof. Barker, 7168.)

We submit that experiments made by Dr. Ravold may show the conditions as to longevity of typhoid bacillus, in laboratory experiments but the evidence above referred to shows that laboratory experiments are more favorable to the longevity of the typhoid bacillus than are the natural conditions. If, then, the life of the typhoid bacillus, as determined by Dr. Ravold in his laboratory experiments, is shown to be as he states from four and three-quarter days in water collected from the Drainage Canal at Lockport to seven days from the examination made of the water taken from the tap in the laboratory at St. Louis, the only logical conclusion which can be arrived at is that in the natural water of the Drainage Canal the life of the typhoid bacillus would be much reduced.

The life of the typhoid bacillus is much shorter in sewage

polluted water than it is in water free from sewage, in fact, this bacteria lives longer in sterilized water than it does in the natural raw water. Dr. Ravold's experiments show this and the evidence of all the witnesses in this case leads to the same conclusion.

Prof. John W. Hill states that the tests he has made show that the typhoid bacilli will live longer in sterilized water. (7516.)

Prof. Jordan says:

"It is my opinion that the introduction of sewage or organic matter of a similar character into the river water is distinctly detrimental to continued longevity or growth on the part of the typhoid fever bacillus. In my judgment the experiments carried out upon the life of the typhoid fever bacillus in the waters of the Drainage Canal show that the presence of a considerable amount of organic matter or sewage in the water favors the speedy dying out of typhoid fever bacilli, rather than its continued vitality. As I have already pointed out this is what might be anticipated in view of the greater concentration of the toxic products of saprophytic microbes in waters highly charged with organic matter than in purer waters.

"This being the case it would follow that typhoid fever germs passing into the river from Peoria would not be favored in any respect by the fact that Chicago sewage had entered the Illinois valley 150 miles above. On the other hand, they might be actually injured by the products originating from the decomposition of such sewage which were carried down even as far as Peoria.

Q. Does the presence of sewage in water add to the longevity or growth of pathogenic bacteria?

A. I have already stated that I considered the presence of sewage in water under natural conditions does not add to the

longevity or growth of pathogenic germs but favors their speedy dying out. (6325.)

Prof. Kinnicutt says:

"All the experiments with which I am familiar show that typhoid germ will live a less time in a polluted water than in a pure water." (7451.)

Prof. Jordan says:

"Q. Will the germ of typhoid live as long in polluted water as in pure or sterilized water?

A. No, sir. I think it will live longer in pure water than in polluted water, and it is well known from the experiments of many observes that it lives longer in sterilized water than in unsterilized.

Q. How do you account of this?

A. I attribute the relatively speedy death of the typhoid bacillus in polluted water, as compared with pure and in unsterilized water as compared with sterilized to the action of the various saprophytic microbes which inhabit these waters. Where the typhoid baccilli are removed from competition with these saprophytic forms, as in the case where they are introduced into sterilized waters, they live longer than under the conditions where they may be injuriously infected by the product of other microbes. In the case of the polluted waters the greater concentration of organic matter may favor a more intense action of the products of the saprophytic microbe present in these waters. In other words, these products in the polluted water are in more concentrated form than is the case in the pure water, and so bring about the death of the typhoid bacillus sooner. It is therefore to the action of the saprophytic microbes that I attribute the dying off of the typhoid bacillus in polluted waters and in unsterilized waters." (6159.)

Prof. Zeit states that typhoid bacilli lives longer in steril-

ized water than they do in natural water. The saprophytic bacteria multiply quickly at the ordinary temperature of river water. These bacteria are found in all sewage in enormous quantity. The pathogenic germs, such as typhoid bacilli multiply only at blood temperature. The result is that in a sewage polluted stream the pathogenic bacteria are rapidly overgrown by the saprophytes and disappear from the mixture. Even in the absence of organic material and where there are only water bacteria present the same conditions exist, but to a somewhat limited extent. The smaller the number of saprophytic bacteria which are present the longer, of course, the typhoid bacilli may exist, and the less they will be overgrown by the rapidly multiplying saprophytic or sewage bacteria or water bacteria. (4422.)

Experimental evidence has shown that the typhoid organism dies out rapidly in sewage polluted water. (Prof. Russell, 6562.)

"From all the knowledge I have been able to gather by study upon this question and from the study of the experiments by Drs. Zeit, Russell and Jordan, it is my opinion that the presence of sewage in water tends to diminish the viability of the typhoid bacillus." (Prof. E. G. Smith, 6825.)

"In the case of a relatively pure water the longevity of typhoid bacillus is greater than in one where it has to fight for existence with saprophytic bacteria. It will not live as long in polluted water as in pure sterilized water. In the case of polluted water it has to struggle for its existence amid adverse germs in great numbers, and it is overgrown. By overgrown, I mean the conditions of its existence are such as to cause it to struggle in the presence of bacteria different from itself, which bacteria are in large numbers and are producing toxins which are interfering with its growth." (W. P. Mason, 6910-6911.)

The foregoing evidence discloses that sewage pollution in-

stead of adding to the longevity of typhoid bacillus causes the speedy destruction of that bacteria. Thus it will be seen that the relative purity of the water has much to do with the life of this microbe organism. When we consider that the sewage of Chicago in passing through the sewers of that city and down the Drainage Canal and Desplaines River consumes an enormous amount of time, the experiments that were conducted by defendants to ascertain the longevity of typhoid bacillus in the waters under consideration in this case and the results that were obtained show conclusively that these results are entirely in accord with the previous experiments made on the subject by other investigators.

An elaborate experiment to determine the longevity of typhoid bacillus in the water of the Drainage Canal and Illinois and Desplaines Rivers was made by Dr. Zeit, Prof. Jordan and Prof. Russell.

The experiment was planned with a view to imitating, as closely as possible, the conditions that would environ a typhoid bacillus introduced into the Drainage Canal from the sewers of Chicago. An effort was made to avoid the serious insurmountable objections to experiments upon the longevity of typhoid bacillus in glass bottles under laboratory conditions. To remove these objections a different receptacle was planned for imprisoning the typhoid bacillus in the Drainage Canal under normal conditions of life, temperature, etc. Five different bodies of water were selected for the experiment, viz.: the water of Lake Michigan, the water of the Chicago River, the Drainage Canal at its mouth at Robey street, the Drainage Canal at Lockport and the Illinois River just above Peoria at Averyville.

Prof. Russell carried on the experiments at Averyville. Under Prof. Jordan's directions experiments were carried on in the waters of the Drainage Canal at Robey street and Lockport. To avoid the use of glass in these experiments

parchment sacks were used. These sacks contained about 800 cubic centimeters of water and were suspended in floats. These parchment sacs permitted the passage of certain substances in solution, but did not permit the bacteria to pass through their walls. The conditions under which the typhoid bacilli introduced into the sewage in these sacs are surrounded are therefore almost precisely the conditions obtaining in nature since the bacteria inside and outside of the sacs cannot pass through the wall of the sacs and yet the bacteria are subjected to the action of the toxic products of the saprophytic microbes in the sewage. The parchment sac in brief acts as a prison for the bacteria. The bacteria themselves are otherwise under the same conditions as those obtaining in the Drainage Canal. These sacs were suspended in the water in a frame work covered with a wire screen which permitted free circulation of the water. The sacs were attached to tubes, these tubes being open to the air at the upper end, allowing a free interchange of the air and gases. The general plan of the experiments and details were discussed by the investigators before the work was undertaken and conferences were also had during the progress of the experiment. It was considered important to obtain cultures of typhoid bacilli, which had not been weakened or attenuated by artificial cultivation and since certain individual differences sometimes exist between cultures obtained from different sources it was deemed necessary to procure several cultures. Three cultures were employed in the experiments carried out by Dr. Jordan, designated as X, Y, and Z. These cultures were obtained from three different partients in the Cook County Hospital, and were freshly isolated for the purposes of this experiment. One of these typhoid bacilli cultures was obtained from the blood of a patient, one from the urine of a patient and one from the feces of another patient. The virulence of these organisms was shown by the fact that in two instances the outcome of the case from which the organism

was taken was fatal. Parchment sacs were selected for use in this experiment for the reason that it was desired to imprison the typhoid bacilli where they might be under observation, and at the same time to imitate as closely as possible the natural conditions. Similar sacs made of celloidin have been used in bacteriological work, and they have been found particularly useful in performing experiments upon animals. Small celloidin sacs filled with a fluid culture of bacteria, have been introduced into the bodies of animals under aseptic conditions. The advantage of the celloidin sacs used in this way is that it permits the soluble products and toxins generated by the bacteria to pass through the wall of the sac while confining the bacteria themselves and not allowing them to spread through the body. This method has shed a good deal of light upon the action of the poisonous products of bacteria, as distinguished from the changes produced in the body by the presence of bacteria themselves. It was thought that by using similar sacs for these experiments upon the longevity of the typhoid bacillus in sewage, the advantages known to be derived from the use of such sacs in animal experiments would be obtained in the experiments upon sewage. In other words, under these conditions the soluble products of the typhoid bacilli would be free to diffuse into the surrounding liquid and conversely, similar products of the sewage bacteria outside of the sac could diffuse into the sac. Any action that these products might have upon the typhoid bacilli could then be exerted under these conditions. The parchment sacs are of substantially the same character as celloidin sacs and the parchment paper of which they are constructed is used commonly in dialysis in the chemical laboratory. The parchment sacs are somewhat stiffer and less fragile than the celloidin sacs and for this reason were used in the experiments in the Canal. Parallel tests with large celloidin sacs of the same size and construction as these parchment sacs have given strictly analogous results.

To sum up, parchment sacs confining typhoid bacilli mingled directly with the contents of the Drainage Canal, represent the natural conditions as closely as it is possible to represent them.

After the cultures were prepared in the manner above indicated they were sent to Prof. Russell and Prof. Zeit.

At Robey street sixteen sacs were used and at Lockport twelve, the sacs being filled with the water of the Drainage Canal at Robey street and then inoculated with the typhoid culture and left floating in the Canal at the place from which the water was taken that was placed in the sac, the same course being pursued at each one of the places where the experiment was tried. In addition a number of sacs were introduced into the water at Robey street and Lockport, which were filled with the sewage or water taken directly from these places and were used as control sacs, the control sacs not being inoculated with typhoid bacilli, but containing simply the raw sewage or water taken from the Canal at the respective points. After the sacs were inoculated with typhoid bacilli, samples of water were taken therefrom. Before taking the samples, however, the contents of the sacs were agitated freely for some time so as to permit a thorough mixing of the contents. During the course of the experiment it was found that after fourteen days some of the sacs would break down, owing to maceration and disintegration in the sewage. After the sample were taken from the sacs the most approved methods of determining whether the typhoid bacilli were present were applied. (See 6180 *et seq.*)

It will be found by reference to the record that four different methods were made use of. A record was kept of each sample of water taken from the sac and the results of the examination for the identification of bacilli contained therein. We respectfully refer the Court to page 6198 *et seq.* for the results of the examinations made.

Table I is the record of experiment carried out in the Drainage Canal at Lockport. The sewage bacteria in the water contained in the sac at the time of its inoculation was 110,000 per cubic centimeter; the number of colon bacilli was 4,000 to 6,000 per cubic centimeter and the number of streptococcus was 1,000 per cubic centimeter. Bacillus typhosus was added to this sewage in such numbers that each sac contained approximately 12,000 typhoid bacilli per cubic centimeter. On the first day after the inoculation of the contents of this sac with the 12,000 typhoid bacteria per cubic centimeter above referred to sixty colonies were taken from the sac and examined, none of which proved to be typhoid bacilli. On the second day seventy colonies were examined; no typhoid bacilli being found. At three days nineteen colonies were taken, none of which proved to be typhoid. At five days twenty-four colonies were picked, at seven days forty-five, and nine days, forty-nine, the typhoid bacilli not being found on either one of the days. This shows that no typhoid bacilli were found in this sac one day after the same were placed therein. (See 6198.)

Table II shows result of experiment at Lockport in waters of the Drainage Canal. This table shows that no typhoid colonies were found in from one to nine days. (6199.)

Table III, Drainage Canal at Lockport. This table shows that colonies were picked off every day for seven days and no typhoid bacilli were found among this number. (6201.)

Table IV, Drainage Canal at Lockport. Colonies were picked off every day from one to ten days, inclusive, without discovering any typhoid bacilli. (6202.)

Table V, Drainage Canal at Lockport. (6203.) This table shows that colonies were picked off for five days, none of which proved to be typhoid. (6204.)

These early experiments gave negative results throughout largely because of the number of typhoid bacilli added in

these cases, but especially because in these early experiments the time allowed to elapse after inoculation before a very large number of colonies were examined was in most cases too great, as is shown by later experiments in which a shorter interval was allowed to elapse between inoculation and examination of the material in these sacs. The experiments, for example, recorded in table IV, where no examinations were made of the water of the sac until after three days elapsed is a case in point.

The outcome of these early experiments convinced those conducting this experiment that if typhoid bacilli were to be found at all in the waters of the Drainage Canal under these conditions it must be by examinations made within a short time after the infection of sacs had been effected. (6204.)

In regard to table VI, showing result of examination made of sac placed in Drainage Canal at Lockport, Prof. Jordan on record 6206 and 7 testifies as follows:

"The table shows that after two days up to ten days no typhoid colonies were found.

Ten minutes after the typhoid bacilli had been introduced varying amounts of the mixture of the sewage and typhoid bacilli were plated in three different media. In one of these cases .001 of a c.c. was plated and there were 45 colonies in all on the plate. Fourteen of these colonies were picked out as looking suspiciously like typhoid colonies and on applying appropriate tests, as already described, 13 of these proved to be genuine typhoid bacilli. From this same sample of water .001 of a c.c. of water was plated and 160 colonies in all developed on the plate. Eighteen of these were picked off as looking like typhoid colonies and 17 of them proved to be genuine typhoid bacilli. Of this same sample .001 of a c.c. was plated in Hiss' medium, 230 colonies developed on the plate, 36 of these were picked off as resembling typhoid colonies and 33 of these proved to be genuine typhoid colonies.

"The fact that on these three different media 63 out of 68 colonies that appeared to be like typhoid colonies turned out to be genuine typhoid organisms, demonstrates the great aid that these special media were in differentiating the typhoid bacillus in the presence of a multitude of sewage forms.

"I consider this as one of the most remarkable of all experiments that were made. On the 10th day after inoculation 1 c.c. of the contents of the sac was plated in Hiss medium and 85 colonies in all developed on this medium, which is not only very favorable to the growth of the typhoid bacillus but to all other sewage forms, its inhibitive effect being less than that of other media. Eighty-five colonies in all developed in 1 c.c. of this sewage, and the whole number of 85 colonies was picked off the plate and examined previously when the sac was inoculated, each c.c. in the sac contained 360,000 typhoid bacilli.

"This experiment plainly shows an enormous mortality among typhoid bacilli under these natural conditions in the water of the Drainage Canal. Examination of one whole c.c. of the water after 10 days shows that of the 360,000 that it originally contained not one was left alive." (6206-7.)

Witness then read in evidence tables VII to XV, inclusive, showing the following conditions and results:

Table VII, Drainage Canal at Robey street. This table shows that colonies were plated from four to fourteen days and no typhoid bacillus found.

Table VIII, Drainage Canal at Robey street. Colonies were plated from two to seven days, inclusive, and no typhoid bacillus found.

Table IX, Drainage Canal at Robey street. Colonies were plated from four to fourteen days, inclusive, and no typhoid bacillus found.

Table X, Drainage Canal at Robey street. Colonies were plated from two to six days and no typhoid found.

Table XI, Drainage Canal at Robey street. Colonies were plated from two to five days and no typhoid found.

Table XII, Drainage Canal at Robey street. Colonies were plated from two to five days and no typhoid found.

Table XIII, Drainage Canal at Robey street. Colonies were plated from one hour to eight days. After one, after 20 hours, after 28 hours, after 2 days, typhoid found. From three to eight days, no typhoid found.

Table XIIIa, Drainage Canal at Robey street. Colonies were plated from three to ten days. No typhoid found until the tenth day when three colonies were discovered.

Table XIV, Drainage Canal at Robey street. Colonies were plated from 20 hours to 9 days. Typhoid found after 20 hours, 28 hours and two days. From two days to nine days, no typhoid found.

Table XV, Drainage Canal at Robey street. Colonies were plated from four days to ten days and no typhoid found.

By using the control sacs, we discovered that there was no such multiplication of bacteria under natural condition as has long been known to occur in glass bottles in the laboratory.

This is one of the reasons for assuming that the conditions in these glass bottles are more favorable for the life of bacteria generally than in nature, and I have already indicated that one possible reason for this favorable effect is to be found in the nature of the substances dissolved by the water.

Tables A, B, C and D, reproduced on pages 6224 to 6227 inclusive, shows results of experiments for the determination of river bacteria. Table A contains records of observations in Canal water at Lockport. The initial number of sewage bacteria per c.c. was 470,000. In 3 days this number had sunk to 2,000. The initial number of colon bacillus in one c.c. was from 4,000 to 6,000. In 9 days the number of colon bacteria had diminished to 5; the number of streptoco-

was in one c.c. was, at the beginning 1,000; at 9 days no streptococcus was found when 10 c.c. of this water was examined.

Table B also shows observations at Lockport, showing a decrease in the number of sewage bacteria, colon bacilli and streptococcus. Table C contains records of observations in the Drainage Canal at Robey street and shows a decrease in sewage bacteria, colon bacilli and streptococcus. Table D shows observations at Robey street with the same results.

"I regard this experiment as being especially interesting in that it shows a slight initial increase similar to what is observed sometimes in the waters of the Drainage Canal flowing between Robey street and Lockport. This very slight initial increase, does not amount to anything like what is observed in samples of this sewage standing in glass bottles in the laboratory.

"I regard the evidence presented by these control sacs as confirming altogether the inferences which I have already drawn concerning the naturalness of the conditions in these parchment sacs. The course of events, so far as the death of sewage bacteria and colon bacilli are concerned is precisely the same as what I have been led to consider happens in the river when these sewage bacteria are added to it in Chicago sewage. In both cases there is the same marked diminution in the number of sewage bacteria and in the number of colon bacilli."

A table of summaries was then read in evidence by witness Jordan. This table shows the combined results of the several experiments made in the Drainage Canal at Lockport. This table shows the following facts:

"One sample was taken ten minutes after inoculation, and out of 68 colonies examined 63 were typhoid. One day after inoculation out of 93 colonies examined none were typhoid.

2 days after inoculation out of 165 colonies examined, none was typhoid.

3 days after inoculation out of 242 colonies examined none was typhoid.

5 days after inoculation out of 136 colonies examined, none was typhoid.

6 days after inoculation out of 17 colonies examined, none was typhoid.

7 days after inoculation out of 119 colonies examined, none was typhoid.

8 days after inoculation out of 24 colonies examined, none was typhoid.

9 days after inoculation out of 59 colonies examined, none was typhoid.

10 days after inoculation out of 110 colonies examined, none was typhoid.

The total number of colonies examined after the date of inoculation was 924. In this number no typhoid colonies were found." (6231.)

A table of summaries was read in evidence on page 6233. This table contained summarized results of the experiment conducted in the water of the Drainage Canal at Robey street, combining the results from the several sacs, the following totals appear:

"1 hour after inoculation out of 49 colonies 41 were typhoid.

20 hours after inoculation out of 104 colonies taken 41 were typhoid.

28 hours after inoculation out of 118 colonies taken 89 were typhoid.

I may say at this point that the reason why a larger proportion of colonies was found in the 28 hour samples than in the 20 hour samples was because a larger quantity of water was examined or plated and this of course resulted in the

appearance of a large number of typhoid like colonies on the plate.

After 2 days inoculation out of 221 colonies examined 10 proved to be typhoid.

3 days after inoculation out of 142 colonies examined none proved to be typhoid.

4 days after inoculation out of 193 colonies examined, none proved to be typhoid.

5 days after inoculation out of 127 colonies examined, none proved to be typhoid.

6 days after inoculation out of 133 colonies examined, none proved to be typhoid.

7 days after inoculation out of 139 colonies examined, none proved to be typhoid.

8 days after inoculation out of 76 colonies examined, none proved to be typhoid.

9 days after inoculation out of 102 colonies examined, none proved to be typhoid.

10 days after inoculation out of 96 colonies examined 3 proved to be typhoid.

11 days after inoculation out of 33 colonies examined, none proved to be typhoid.

12 days after inoculation out of 75 colonies examined, none proved to be typhoid.

14 days after inoculation out of 50 colonies examined, none proved to be typhoid." (6324.)

These summaries show that three days after inoculation the typhoid bacilli were not found, being an indication, of course, that they survive only for about two days and one-half in the water of the Drainage Canal at Robey street. A similar experiment was conducted by Prof. Jordan, using lake water instead of river water, both celloidin and parchment

sacs being used, and in no case was the typhoid bacilli found, after a period of four days, showing that the typhoid bacilli in this water lived twice as long as they did in the water of the Drainage Canal at Robey street. This experiment also showed that the conditions surrounding the bacilli are substantially the same, whether they are imprisoned in parchment or celloidin. Prof. Jordan was interrogated as follows on page 6238:

"Q. From the result of these experiments what conclusion do you draw as to the longevity of the typhoid bacillus in the water of Lake Michigan?

"A. It was found by actual experiment under conditions which I believe to simulate closely in nature that the typhoid bacillus, introduced into sterilized Lake Michigan water was recovered four days after inoculation and was not found in subsequent examinations made up to the end of the fifteenth day. It is probable that specially resistant individual cells might survive longer than appeared to be the case in the experiment described in my testimony, but in my opinion even such highly resistant individuals, if they did exist, would not live more than about twice as long as the time recorded in these experiments. So that I conclude that 8 to 10 days would be a maximum period of longevity for the typhoid bacillus in the water of Lake Michigan, under natural conditions.

These experiments, of which a large number were made with varying numbers of typhoid bacilli introduced directly into the water of the Drainage Canal, gave generally uniform results. It was not difficult to discover typhoid bacilli during the first two days. Later than that they were never found either at Lockport or at Robey street, with one exception. In this anomolous case, 3 typhoid bacilli were isolated on the 10th day from a single plate in a single sac.

Taking into consideration all of the experiments made in

the waters of the Drainage Canal, and assuming, as before, that specially resistant individual cells might exist, which would live twice as long as those found it is my opinion that typhoid bacilli introduced into the waters of the Drainage Canal, under natural conditions, would not and do not live in that situation longer than four days.

Remembering that the upper stretches of the Illinois River are highly polluted with sewage and that considerable additions of sewage are made to the Illinois River at points along its course, I do not believe that bacilli introduced into the Desplaines or upper portion of the Illinois River would live under natural conditions more than five or six days.

It is my opinion that a typhoid bacillus, discharged from the body of a typhoid patient in Chicago and assuming that such discharges were not disinfected so that the bacillus could pass into the sewers of Chicago and thence into the Chicago River and Drainage Canal, might live as long as 3 or 4 days after leaving the body of the patient." (6238-9.)

Prof. Jordan also testified:

"In the experiments as reported there is one instance where typhoid bacilli were found in a single case, on the 10th day. The singularity of this finding and its isolation from all of the other results that were obtained in the course of examination of a large number of sacs, over a long period of time in my opinion demands a special examination.

"The sudden appearance of three colonies in the sac after an interval of eight days, during which no typhoid bacilli were found, although a large number of colonies were examined, points to some unusual occurrence. The most reasonable explanation seems to me to be that at the time when the contents of the sac were heavily infected with typhoid bacilli, during the progress of tilting and agitation previously referred to same concrete particle in the sewage to which typhoid bacteria adhering was deposited and became dried upon the walls of

the sac above the water line. Under these conditions it is my opinion that the typhoid bacillus might remain alive for some time.

"Such a dried particle, containing living typhoid bacilli might conceivably be washed off from the place where it had lodged. These typhoid bacilli suddenly introduced into the sac after an interval of 10 days might appear on the plate and be found, as in this case. It is certainly difficult to account otherwise for the sudden appearance of three colonies and for their occurring only on one plate. If these typhoid bacilli had remained alive in the water of the sac throughout this whole period, it would be expected that between the second day and the 10th day other resistant individual germs, straggling survivors of the great multitude originally introduced, would also have appeared on some plates and been picked off and identified.

"I am inclined to believe, therefore, that this isolated case was due to an accident occurring under the conditions in which the experiment was conducted, and does not indicate that typhoid bacilli would survive as long as ten days in the water of the Drainage Canal itself. The outcome of all the other experiments made it distinctly opposite to the latter view.

Answering your question, then, as to the significance of the whole experiment, I would say that in my opinion it indicates a longevity of the typhoid bacillus in the polluted water of the Drainage Canal of not more than three or four days." (6239.)

Prof. Zeit testifies as to the part he took in this experiment and the results of same as follows (See 6421 *et seq.*):

"Since giving my testimony I have made an experiment upon the longevity of the typhoid bacillus in conjunction with Prof. Jordan and Prof. Russell. The plan outlined by Prof. Jordan was that substantially followed by me, and each was

to do his respective work at stations selected. I adopted two plans: the first was to use parchment sacs; the second was to use celloidin sacs, both intended to allow osmosis, and both to contain the typhoid bacillus. In the presence of the normal saprophytes present in the water of Lake Michigan and the Chicago River, the parchment and celloidin sacs both allowed osmosis to take place.

"The sacs were suspended in the Chicago River at the Ashland avenue bridge, and similar sacs were suspended in a jar of water through which fresh Lake Michigan tap water was constantly flowing. The boxes were prepared in the same manner in which Prof. Jordan prepared his. The sacs were seeded with typhoid bacillus after they were first filled with river water; so as to make the sacs a mixture containing 200,000 and 1,500,000 typhoid bacilli per c.c. We used an average suspension of 500,000 typhoid bacilli to the c.c. in each sac.

"The first samples were taken from the sacs about twenty-four hours after the sacs were placed in the water, and daily after that. There were eight experiments made at each place. That is, eight experiments at the Ashland avenue bridge on the river water and eight experiments made in flowing lake water from the tap of the Post-Graduate Laboratory.

Q. Will you state in detail the results that you obtained from all these experiments made by you at Ashland avenue?

A. In all the experiments with a surprising similiarity we found that during the first twenty-four hours the total number of bacteria would greatly increase, and typhoid bacilli could be found even with the increasing numbers of all bacteria present in the sac, and that typhoid bacilli were found for the next day, during which the total number of bacteria greatly decreased, and from now on the total number of bacteria continued to decrease, except the typhoid bacilli which

were found for three days at the most in the Chicago River water. It was impossible after three days in any particular sac to find typhoid bacilli. There was no difference in the results of the experiments between the parchment sac and the celloidin sac; in both there was great increase of all bacteria for twenty-four hours. Then the number dropped from day to day, and no typhoid bacilli could be found after the third day; in some of the experiments after two days we found no typhoid bacilli. The longest we ever found them was three days. In the parchment sacs we would examine for fifteen days; in one instance for twenty days. In the celloidin sacs we followed it up as many days as we had sacs. We started out to have ten sacs for ten days; occasionally one would get broken, and the minimum was eight sacs for one of the celloidin experiments.

"The reason I mention this is because in some of my former testimony I laid particular stress upon the fact that I thought the disappearance of the typhoid bacillus in the experiments reported at that time was probably due to the overgrowth of saprophytic bacteria, whereas, as the result of these experiments, I conclude that there are in this river water certain substances, possibly excreted substances of saprophytes, which alone are sufficient to prevent the growth of the typhoid bacillus, and even destroy it within a very short time.

"We have also made experiments in which we inoculated a typhoid bacillus into boiled river water, and in these experiments the bacillus lived longer than it did in the raw but filtered river water. In boiled river water, which contained no living bacteria, into which we inoculated typhoid bacilli, they would live longer than they would in unboiled filtered sterile river water by about three days. In the parchment sacs the longest they lived was three days. I made one experiment, in which I added to the water from a parchment sac immune serum of this horse and collected the precipitate in the form of

a conical glass tube, hoping that if I had escaped any typhoid bacilli by the other methods this way I could enrich the number of typhoid bicilli, if any had been left alive. I tried this several times, always adding the serum of the immune horse, hoping to agglutinate and precipitate the typhoid bacilli of the whole quantity of water used before getting to the bottom, pouring off the rest and adding nutrient material to the residue, because it is a fact that immune serum agglutinates typhoid bacilli, but will not kill them. I was entirely unsuccessful here in finding typhoid bacilli, probably because these experiments were only made after the other experiments showed the disappearance of typhoid bacilli. I was unsuccessful after the third day in the river water by this method to find any typhoid bacilli.

"The number of c.c. in a liter is 1,000.

"I would say that in the manner employed here of using a membrane that allowed osmosis of the fluid outside of the sac in the river, as well as the excresence of the bacteria multiplying inside of the sac to pass freely in and out, conditions were produced which were as nearly those existing in nature as could be artificially produced. This experiment sheds more light upon the true conditions of the longevity of the typhoid bacillus in polluted streams than we have known in the past.

"The fact that even in the raw filtered river water, free of all saprophytes, typhoid bacilli die rapidly, is evidence that there is in this water something which destroys the typhoid bacillus quickly. That effect must vary in different rivers, and such variation is due to the greater or lesser presence of substances excreted by saprophytes, which explains the greatly varying statements of different authors.

"In the experiment with Lake Michigan water we used parchment and also celloidin sacs. * * * During the first four or five days we were largely successful in picking out a typhoid suspicious colony from one of these plates, which imme-

diately gave a Widal test, so that would be set aside. The longest that we found typhoid bacillus here was for eight days. At the time when they did appear on the ninth day we would take every colony on all of the plates and inoculate every one into Hiss tubes. The longest that we found typoih bacilli was eight days. Some times we did not find any after four days.

Q. Professor, does this experiment which you have made and introduced furnish you with any basis for an opinion as to the life of a typhoid bacillus in the water of the Chicago River and Drainage Canal and Illinois River?

A. Yes, sir. As the result of the experiments which have been made by all of us, Prof. Jordan, Prof. Russell and myself, I am of the opinion that typhoid bacilli cannot live in the Drainage Canal or in the Chicago River or the Illinois River for more than three days." (6421-36.)

Prof. Russell conducted that part of the experiment relating to the longevity of the typhoid bacillus in the Illinois River at Averyville, which is located just above Peoria. Fifteen different sacs were used by this witness. No typhoid bacilli were found in the sacs after a period of three days, with the exception of the one colony which was found on the 9th day, and to which so much stress is laid by counsel on pages 172, 3, 4, 5 and 176 of their argument. The cross-examination, which is quoted by counsel, speaks for itself. He states as quoted by counsel on page 176 of their argument "I should consider that a conclusion, which is based on the results, which were obtained in the case of this single organism alone, and not the whole results of the experiment, are not proper as indicating what the conditions of affairs would be, which would occur in nature."

Prof. Jordan's explanation for the finding of this germ on the 9th day, which we have heretofore quoted, sufficiently answers this question.

We respectfully refer the Court to the testimony of Prof. Russell where he gives the results of his experiments. (6512-6513.)

The sacs were examined for sixteen days, and no typhoid bacilli were found after the third day, except the one colony above referred to upon the ninth day, and this colony, we submit, is explained by Prof. Jordan's statement above referred to.

Prof. Russel testifies as follows:

"In addition to the series which were made with the parchment sacs another method was used which approached the problem from a different point of view. Ordinary commercial agar was taken and washed in running water for several days, to remove all soluble products. From the prepared agar small rectangular blocks were cut out. These blocks were inoculated with freshly grown typhoid cultures by means of a platinum wire and the top of the block was sealed by means of searing the surface with a hot iron. According to Oswald, the eminent German physicist, this soluble agar possesses the property of allowing diffusion to take place quite as rapidly through its substance as would be the case in water itself. Hence, it follows that if typhoid organisms were placed on the interior of an agar mass and then exposed in an aqueous medium containing bacteria of various kinds, then the typhoid organism would be subjected to the influences which would arise from the growth and development of these water or sewage bacteria in the surrounding media in which these agar blocks were immersed.

"The summary of the results of these cultures on the vitality of the typhoid fever organisms, inoculated in numbers, so large that the number of organisms produced turbidity to be recognizable with the unaided eye, that the exposure of these numerous typhoid organisms in the waters of the Illinois River and also in the waters of Lake Mendota at Madi-

son, resulted in loss of vitality of this enormous number of typhoid bacteria to such an extent that in no case were any typhoid organisms found after the eighth day and in the case of one series none was found even on the first day. This variation in the vitality of the typhoid cultures, where an indefinite number of organisms were inoculated, under these conditions, and where it was not exposed directly to the competition which exist between water and sewage bacteria and the typhoid organism is more surprising, as the organism was not directly exposed to the influences of the competing bacteria themselves but merely to the soluble products which these germs are capable of producing.

"In the case of the parchment sacs the typhoid bacteria were exposed to the direct contact of all the water or other bacteria which might be present in the samples of water which were placed in the sacs. In the case of the agar blocks the typhoid organisms were not exposed to this direct contact but were exposed to those products of the metobolic activity of water and other bacteria which might be present in the outside medium and which would find it possible, if in solution, to pass through the agar block, by diffusion, and so possibly act upon the typhoid bacteria themselves which were screened by these agar blocks.

"I find that the experiments made with agar blocks give more favorable conditions for the retention of the vitality of the typhoid organism than was the case in the parchment sacs where the contact of typhoid organisms with other bacteria was rendered possible.

"I should consider that the typhoid organisms deposited in the waters of the Chicago River and Drainage Canal would have a much shorter duration of vitality than in waters of Lake Michigan and that such vitality would not extend to a period of more than two or three days. From the results obtained in this combined experiment with Prof. Jordan and

Prof. Zeit I should say that the longevity of the typhoid organism immersed in the waters of Lake Michigan would be considerably longer than in the waters of the Chicago River and the organism would probably be able to live for a period of six or eight days.

"From experiments which I have actually made when freshly isolated cultures of bacillus typhosus were exposed in permeable sacs in varying numbers so that the germ content of the typhoid organism exceeded at least the germ content of the water used in the ratio of 100 to 1 or more, and where the organisms were destroyed in the course of about three days, with one possible exception, and that if this was the condition which was obtained under the conditions in which the experiment was made, when the effect of other environmental factors were excluded, such as the influence which would come from sedimentation, dilution, influence of light, vital concurrence with green plant forms which might be found in the waters of such river, I should certainly consider that the life of the typhoid organisms when subjected to the more severe conditions which obtain in the waters of the Illinois River itself than was the case in the experiments with the parchment sacs, that it certainly would be no longer in the waters of the Illinois River and in all probability would be shorter, hence I would conclude from the foregoing data that the vitality of the typhoid organism would not in any case be maintained for more than a period of a very few days, three or four at the outside.

"In view of the above experiments and other conditions, I am of the opinion that typhoid organisms finding their way through the sewers of Chicago, into the Chicago River and thence into the Drainage Canal, down the Desplaines and into the Illinois River would be destroyed before such water had passed the course of the Illinois River.

"I would consider that if the longevity of the typhoid bacil-

lus be impaired by the action of sewage and the water bacteria of a polluted stream that at least the same, if not a greater effect would be produced if the typhoid organism was in contact with these bacteria and the products of their growth in the sediment of such a stream." (6520-1-2-3.)

The above experiments were carried out by three eminent scientists, who are foremost in the lines of their profession. These experiments were conducted independently of each other and at different points, and still the results are the same. It is not necessary, we contend that we should take the opinion of an epidemiologist, who forms his conclusions by methods of deduction, when we have before us the actual results obtained from an examination of the very waters in question in this proceeding. The experiments above referred to are admittedly the most extensive that have ever been undertaken to ascertain the longevity of typhoid bacillus. They were more similar to the conditions in nature than laboratory experiments and show conclusively that typhoid bacilli can only survive at the most two days in the Drainage Canal and three days in the Illinois River.

Prof. E. G. Smith states that he has read of the experiments conducted by Profs. Jordan, Zeit and Russell, and states that he first suggested the carrying out of these experiments.

"From such a study as I have been able to make of the quality of the waters in the Canal and the Desplaines and the Illinois Rivers, and from the study, especially of the work of Prof. Jordan, it is my opinion that the viability or duration of life of the typhoid bacillus must be brief, surviving but two or three days, so far as those experiments show, not extending beyond that." (6753.)

Dr. Herbert E. Smith, a witness for complainant, testifies as follows on page 7749 of the record:

"Q. Do you know of any experiments that have been

made by any bacteriologist in this country or in Europe that simulates natural conditions as nearly as the experiments made by Profs. Jordan, Zeit and Russell, to which you referred, and which were as extensive in their scope as that experiment upon the longevity of the typhoid bacilli?

A. No, sir; I do not."

Prof. Theo. Smith says:

"The results of Professors Jordan, Zeit and Russell have introduced a new factor into the problem in that they have defined for us, perhaps for the first time, the viability of the typhoid bacillus in polluted water. Before that time of course the results were not very definite unless we took into account the viability of the colon bacillus, but now it seems that the typhoid bacillus is fairly rapidly destroyed in polluted water, more rapidly than we have believed, and that rapidity of destruction would indicate what I suggested a moment ago, that possibly the typhoid bacillus is stimulated enough to multiply in sewage polluted water to be promptly destroyed whereas in water which contains very little organic matter its life is preserved a longer time because of a condition of latency and absence of that stimulation to multiply which I assume is very destructive to bacteria in general. If these experiments are correct, and I feel quite prepared to take the risk of accepting all of those experiments of Professors Jordan and the other gentlemen—if they are correct—then I think it would be physically impossible for the typhoid bacillus to reach St. Louis, starting at Chicago." (7305.)

Prof. John W. Hill made extensive experiments on the longevity of typhoid bacillus in the Delaware River, and he states on record 7509 that as a result of these experiments he found "that its life history was limited to from five to eight days under the most favorable conditions."

Prof. Hill's experiments were laboratory experiments, how-

ever, and on water very much less polluted than that of the Drainage Canal or Illinois River. The water used, also, in these experiments by Mr. Hill was sterilized. He states that he would put the life of the typhoid organism in a sewage polluted river water under normal conditions, which prevail with the maiority of the rivers in the United States, at from five to eight days.

Dr. L. F. Barker states the life of the typhoid bacillus to to be from five to seven days. (7103.)

Counsel quotes Dr. Ravold on page 169 of their argument "It is impossible to determine the absolute longevity of typhoid bacillus in running water because the conditions, which obtain in a stream, cannot be produced in laboratory experiments." That is the reason defendants made these experiments above referred to, which are admitted to be closer to natural conditions than laboratory experiments. Dr. Ravold is again quoted on the same page as saying that "the typhoid bacillus is a mover and can swim out of the way of anything that would be deleterious in a river."

Prof. Jordan testified as follows on page 6399 of the record:

"Some investigations have lately been published on the speed of a typhoid bacillus in the Archiv fur. Hygiene, 1903, 46, page 311, by Lehmann and Fried. These show the results of careful measurements made of the speed of the typhoid bacillus and other bacteria. The mean of the highest and the mean of the lowest observations are given in this paper. Moving at the highest speed a typhoid bacillus was found to move at the rate of *four and one-half inches in an hour*, the minimum rate being about one-fifth of this. From one to five inches per hour, therefore would represent the speed with which a typhoid bacillus would move. In a river flowing at the rate of half a mile an hour the velocity of the current would be about 5,000 times as great as that of the

typhoid bacillus, so that this organism would be helplessly borne along and brought into contact with various toxic substances without being able to remove itself from their neighborhood."

We have heretofore quoted evidence showing that the longevity in a running stream is a great deal less than laboratory experiments owing to the fact that the typhoid bacillus in a running stream comes in contact with many substances, toxins, etc., differences in temperature, etc., which do not exist in laboratory experiments and which completely answer the statements of Dr. Ravold on pages 169 and 170 of complainant's argument. The statement attributed to Prof. Sedgwick on page 171 of argument for complainant, as will be seen by reference to page 2315 of record, are based on the assumption that typhoid bacteria will live longer in sewage polluted streams than in pure water. Mr. Sedgwick is the only witness on behalf of either defendant or complainant in this case that holds to that position.

Page 2665, which is quoted by counsel as sustaining the contention made by Prof. Fuller that typhoid fever germs will live in sewage polluted waters for a period of weeks and months, shows that he bases his opinion upon that of Prof. Sedgwick. He also states that he has not personally conversed with a great many people on the subject and that he cannot recall any one who has exploited the extreme views he has for the longevity of typhoid bacillus. He states on record 2663 that his common knowledge of the existing conditions of many country towns satisfies him beyond all doubt as a scientific man that those germs live for at least a year. He was then asked, "Is your common knowledge superior to scientific demonstration?" to which he replied, "In a great many instances it is vastly superior to it." (2663-4.) This witness has never made experiments nor can it be found anywhere in the record of his testimony that he or Prof. Sedgwick

give any reason for the opinion which they hold, which opinion is contrary to all the evidence in this case.

Counsel quotes Dr. Barker on page 170 of their argument as saying that typhoid bacilli would or might live as long as ten days, but that he does not think that it would live as long as thirty days. By reference to 7167 of the record quoted by counsel it will be seen that this witness made this reply in answer to a question asking how long typhoid germ will live in running water without any special sewage contamination. This answer then would not apply to typhoid germs in the sewers of Chicago and Drainage Canal. It will also be noted by reference to pages 7167--8-9 that this witness was very reticent as to testifying on this subject. On page 7169 this witness states that they die very quickly where the sewage is abundant. On the same page he states he would rather not express an opinion as to how long they would live in the Illinois River.

As to the experiments made by Mr. Hill, referred to by counsel on page 178 of their argument, we have heretofore quoted this witness as stating:

"I should put the life of the typhoid organism in a sewage polluted water under normal conditions, which prevail with the majority of rivers in the United States drawn on as the sources of public water supply, at from five to eight days." (7517.)

He further says:

"Was this test made on the sterilized or unsterilized water?

A. On sterilized water.

Q. Why was sterilized water selected?

A. Because it was thought to be more favorable to the growth of the organism than unsterilized water, and because it eliminated the danges of our failure to detect the typhoid organisms after a few days of growth, no other organism

growing in the water excepting that due to the inoculation of the test flasks." (7516.)

This experiment having been made on sterilized water coming from an ordinarily sewage polluted stream, we insist that this experiment agrees with the experiments made by Drs. Zeit, Prof. Russell and Prof. Jordan. We have heretofore shown that the longevity of typhoid bacillus is much longer in sterilized water than it is in raw water. Indeed, Prof. Ravold's experiments are decisive on this point. As Mr. Hill says, the water being sterilized prevented any other organism from growing in the water. The typhoid bacillus then, were not subjected to the action of saprophytic bacteria—in fact the typhoid bacillus thus had no inimical conditions to contend with. When we take into consideration that laboratory experiments as heretofore shown are more favorable to the life of the typhoid bacillus than are the conditions in nature we can come to no other conclusion but that the life of the typhoid bacillus in the highly polluted waters of the Drainage Canal surrounded by the saprophytic bacteria, toxic and other injurious influences is less than two days as was shown by the experiments conducted by witnesses for defendants. Counsel say that the Schuylkill is a more polluted stream than the Illinois River. Upon turning to the pages of the record referred to by counsel we do not find that the record sustains such a statement, in fact, the Schuylkill is used for a water supply.

If the results of this experiment made with sterilized water from an ordinarily sewage polluted stream leads Mr. Hill to state that the life of the typhoid organism is in the ordinary streams, under conditions that prevail in the United States, is from five to eight days, then we submit that their experiments corroborates the experiments made by Jordan, Zeit and Russell in highly polluted water of the Drainage Canal in their natural condition, under conditions which simulate nature

better than any other experiment that has ever been made, when they find that the typhoid bacillus has a life history of less than two days in the Drainage Canal.

We have already explained the reason for finding typhoid bacilli on the tenth day in one of the sac experiments by Dr. Jordan. This was only found on one occasion and the reasons for same given, but counsel set out this part of the testimony on page 179 of the argument in such a way as to lead the Court to believe that the result of the experiment was to find the life history of the typhoid bacillus in the Drainage Canal to be ten days.

As to the statement of Prof. Jordan, quoted from page 6239 of the record on page 179 of argument, we wish to call the Court's attention to the fact that this relates to the Illinois River, and that witness states: "I do not believe that bacilli introduced into the Desplaines or uppor portion of the Illinois River would live under natural conditions more than five or six days." We are pleased that counsel accept this as the true condition of affairs, by quoting same in their argument. The fact is if bacilli introduced in the Desplaines or uppor portion of the Illinois River, live only five or six days, bacilli introduced into the sewers of Chicago, thence into the Chicago River and Drainage Canal could not be expected to live more than two days.

The statement of Prof. Jordan as to the longevity of typhoid bacilli in rural communities and when emptied into loosely constructed privy vaults or out houses, has no connection with the longevity of bacillus coming from the sewers of Chicago and going down the Chicago River and Drainage Canal, and we insist is not in point.

We respectfully refer the Court to pages 2081-2 of the record referred to by counsel as sustaining the statement made on the first half of page 180 of their argument that

"Experiments upon the longevity of the typhoid bacillus

have been made in the laboratory where the question of motion, sunlight and air were taken into account, and it was found that it varied from a period of some weeks to some months." (Whipple, cross-examination, 2081-2.)

The examination of this witness on that subject begins on page 2081, and is as follows:

"Do you know whether there has ever been a test of typhoid germs in sewage polluted water made in the laboratory?

A. Yes, sir.

Q. You know how long they would live in that water, subject to sunlight and air and motion, do you?

A. I do not recall the experiments made to determine the longevity of the typhoid bacillus by laboratory experiments in water, where the question of *motion* was taken into account, but I know of experiments which have been made in sewage polluted waters where the question of *sunlight* and *air* were taken into account. In fact, I know of a number of experiments which have been made and the longevity was found to vary from a period of some weeks to a period of some months. I cannot at this moment give the exact results reached by those observers. I have also made experiments on the subject myself.

Q. Were those experiments conducted in the laboratory similar to conditions that exist in running streams?

A. No, sir, the conditions were not the same as would exist in running streams in all respects:"

As to when the experiments were made, by whom they were made, what the temperature of the water was, whether the water was sewage polluted or not, whether sterilized or in its natural condition, is not stated by witness. For these reasons this statement ought not to be taken into consideration by the Court.

As to the statement of Prof. Sedgwick, quoted on page 181

of argument, that large numbers of typhoid germs might be deposited in the bed of Lake Peoria for a period of months and if so deposited would not be entirely destroyed at the end of that time, etc., we refer the Court to the following testimony of Prof Russell:

"I consider the assumption that typhoid fever could pass from the sewers of Chicago, by way of the Drainage Canal to Lake Peoria, and be deposited there in the bed of that lake for a period of one month as one that is untenable, and in the light of experimental inquiry not in accord with the facts, and it is my opinion that under no normal conditions which could obtain in nature as they now exist that the typhoid germs would be able to pass from Chicago to Peoria and not be destroyed before the end of the period covered by the question.

Taking all of the conditions into consideration that obtain in the Drainage Canal, the Desplaines and the Illinois Rivers, as to the probable logevity of the typhoid bacilli in the waters of such stream, I should consider that at no time under natural conditions would such conditions exist as would cause the waters of the Illinois River leaving Lake Peoria to contain more infectious and dangerous pollution than would exist in the diluted sewage of the Drainage Canal, passing the Bear Trap dam." (6564-5-6-7.)

The following witnesses testified to the same effect: W. P. Mason (6939-40), Prof. Jordan (6315-16), Prof. Kinnicutt (7452), Prof. E. G. Smith (6818-19).

Counsel for complainant as seen by their quotations of Prof. Sedgwick's and Williams' testimony in relation to typhoid living in sediment and afterwards being flushed out by floods, etc., seem to contend that the longevity of typhoid bacillus is longer in sediment than it is in water. We submit that the experiment conducted by Profs. Zeit, Jordan and Russell placed the typhoid bacillus in the same condition as

they would be in the sediment of a stream, for the reason that the celloidin sacs in which the experiments were made were anchored and remained in one spot during the entire course of the experiment. In other words, the typhoid bacteria were stationary just as they would be in sediment with the water flowing past them. As above shown these celloidin sacs allowed the ingress and egress of toxic and saprophytic products and simulated as closely as could be done by an experiment the natural conditions of typhoid bacilli living in sediment. We therefore submit that as to the waters of the Chicago River, Drainage Canal and the Illinois River this experiment is conclusive as to the longevity of typhoid bacillus contained in sediment. If it be true as contended by counsel that the life of the typhoid bacillus is longer in sediment than in water, then the life of that bacterium would have been found to be still less, had it been possible to allow the celloidin sacs to float down the stream. The experiments made show conclusively that typhoid bacilli will die in sediment of the Chicago River; Drainage Canal and Illinois River in from two to four days and that in the flowing water their life would even be much shorter. Taking into consideration the evidence that will be hereafter referred to of government employes in charge of dredging operations in the Illinois River, who testified unequivocally that there was no scouring in the Illinois River, we submit that there is no danger to the City of St. Louis from typhoid bacteria deposited in the sewers of Chicago, as such typhoid bacteria are shown to die out in from two to four days and the lowest time found by complainant in which the water flowed from the south fork of the Chicago River to the St. Louis intake is ten and one-half days to which must be aded two days during which the water remains in the sedimentation basins in St. Louis and also the time consumed for the supposed bacillus to travel from the point of deposit in the Chicago sewers through said sewers to the Chicago River and down the Chicago River to the end

of the south fork thereof, where complainant's float experiments were begun.

Prof. Jordan was also asked in relation to the question of the storage of water for a period of thirty days and the prevalence of typhoid fever in a community where such a system is in vogue, and testified as follows (6252):

"Q. When a settling basin holds a sufficient amount of water to supply the city for a period of thirty days, and as the water is taken out for domestic uses, raw water is immediately supplied, and typhoid fever should prevail among the people using said water, what is your opinion whether such a condition justifies the assumption that because the reservoir holds a supply for a period of thirty days, that a typhoid bacillus will live in that water for such a period?

A. In reply I will state that I should wish to investigate thoroughly the conditions surrounding a community so situated and to determine to my satisfaction that the water supply in the settling basin was the source of the typhoid fever prevailing among the people. Some further points would also have to be considered.

As I understand the situation described it is not true that all the water pumped into the settling basin would remain there for a period of thirty days, allowing that length of water would be drawn continually from the reservoir during this period of thirty days.

Such being the case it seems to me obvious that not all of the water drawn from the reservoir could have remained in the reservoir for a period of as long as thirty days. Some of it in fact may be drawn from the reservoir within a very short time after its entrance into said reservoir, possibly within 24 or 48 hours of its being taken from the river. Any typhoid germs introduced in this way might be drawn out from the reservoir without having remained in it for a period as long as that mentioned.

It does not seem to me to follow because a reservoir or settling basin holds a thirty days' supply that all typhoid bacilli introduced into the reservoir remain there for thirty days."

This answers the statements of Prof Sedgwick, quoted by counsel on page 182 of their argument.

It will also be noted by reference to the statement quoted by counsel on pages 180-1 of their argument that Mr. Sedgwick relies upon the facts set out by Mr. Williams in relation to the Detroit epidemic as a basis for his assumptions in regard to the existence of typhoid bacilli in the slack waters of the Illinois River and in the bed of Peoria Lake. We have already discussed the epidemic at Detroit and demonstrated that such epidemic could not be traced to the drainage of the harbor at Port Huron.

Prof. Sedgwick is the only witness in this case who makes the statements above referred to by counsel on pages 180 to 183 of their argument. It will be noted by the Court that no other witness for complainant is cited by counsel to sustain those contentions. This is because no other witness testified to such facts. Every witness for defendant when interrogated in regard to the statements made by Prof. Sedgwick took issue with him. It will thus be seen that Prof. Sedgwick stands alone in this volumnuous record in taking the position set forth in the argument of counsel, but this is not the only erroneous statement made by this witness. He also stands alone in stating that sewage tends to increase the life of pathogenic germs. Nowhere in the record can be found the utterance of a single witness, either for complainant or defendant that sustains Prof. Sedgwick in his over zealous and extreme contentions.

18.

"THE VELOCITY OF ILLINOIS RIVER, OR THE TIME IN WHICH IT TRAVELS FROM CHICAGO TO ST. LOUIS."

Counsel open this part of the argument on page 183, with the statement "It is necessary to know approximately the time required for water to pass from Chicago to St. Louis in order to determine whether or not typhoid fever germs and other pathogenic bacteria will pass from Chicago to St. Louis alive and virulent." It is true that if it were possible to ascertain approximately the time required for any particular portion of the water in the Chicago River to pass down to St. Louis, such knowledge would be of value if it were shown that the typhoid bacilli remained in that particular portion of the water during the entire journey without sedimentation and without being thrown to one side of the river or without perishing during the journey.

Prof. Van Ornum states on record 1747, that at the time this experiment was made in general the Illinois River was high.

"Q. Was it very high? A. Yes, sir.

Q. The bottom lands and the over flowed lands along the Illinois River were very extensive, was it not? A. Yes, sir.

Q. The river was some times four or five miles wide in very high water? A. It may be.

Q. From water line to water line? A. Yes, sir.

Q. Varying of course with reference to the proximity of the high lands to the river? A. Yes, sir.

Q. Well, the ordinary banks of the river at all places were over flowed with water? A. Yes, sir.

Q. The water extended out into the bottoms.

A. Yes, sir." (1748.)

"At the time these experiments were made the river was much higher than the average of the river, in fact, it was over flowing the low lands. The necessary accompanyment of that fact is that the current was swifter and there was drift wood running." (1768.)

"It is a fact that at the time this experiment was made there was a great amount of flood water in the Illinois River." (1796.)

"Q. The river had over flowed its bank from La Salle practically to Grafton, hadn't it?

A. I couldn't say, certainly; I think so through the larger part of that distance, certainly." (1770.)

This experiment was made under the most favorable circumstances and when the current of the river was at its swiftest.

"Q. How did the water along the over flowed banks compare in velocity of current with that in the channel?

A. Very much slower.

Q. Was the water in the basins beyond the banks of the river or rather did the water in the basins of the over flowed land have any perceptible current?

A. As far as I saw it was barely preceptible.

Q. It was practically in a stagnant slow condition, was it not?

A. As far as I saw it." (1772.)

"Q. From your observations in this experiment are you able to tell what the velocity of the current would be, if the Illinois River was contained within its banks?

A. No, sir." (1773.)

This experiment only determined the quickest time of the most swiftly flowing water from Lockport to Grafton. The general tendency of the floats was towards separation and

going to the shore. In other words, the tendency of the floats was to seek the banks; get out of the swiftly moving current into the water on the side of the river which, according to the testimony of the witness, had no preceptible current. It was found that they were frequently aground and had to be released and taken back to some deeper point. (1749.)

"Q. Did you put that float in the middle of the river—in the middle of the current?

A. It was in the middle of the current a part of the time. I would put a float in the river and try to put it where I thought the point of maximum flow was. Whenever that float appeared to be working too much to one side I would go out and drop another float opposite to the first one and then let them both run from there and see which was running the fastest and then take up the one that was lagging behind." (Merseran, 1805.)

This witness also states that he took the fastest float and if the float began to get slow he would put in another one opposite it.

"When a float went astray and got out of the current or went aground it was taken out and put back into the current opposite to where it was taken out." (Frank J. Brown, 1825.)

"Some floats would drop way behind and go to one shore or the other and would have to be taken out." (1828.)

"The floats drifted aground some time and went to the bank and had to be taken out and placed in the current again." (Jos. E. Gibson, 1833.)

"One float was lost in the brush in the Desplaines River. The floats continually went to the shore and had to be taken out again." (Thos. F. Reed, 1843.)

This evidence of the persons who conducted the experiments we submit show conclusively that the conditions were

most favorable and that the results show the shortest time necessary for a float to travel down the center thread of the channel. The testimony further shows that had not these floats been constantly picked up, as they went ashore, and again placed in the current they would never have reached the mouth of the Illinois River. This experiment then casts no light upon the question as to how long it will take a float to make the journey from Chicago to St. Louis unaided by human agency. When we consider that the evidence in this case shows that bacteria are particulate particles, having a specific gravity heavier than water and that sedimentation of these micro-organisms takes place in water we fail to see of what benefit the float experiment may be in determining the length of time necessary for the transportation of bacilli from Chicago to St. Louis by way of the Chicago River, Drainage Canal and the Illinois River. Were it possible for the typhoid bacteria leaving the sewers of the City of Chicago to survive the passage to St. Louis and were it further possible that these bacteria could be followed on their journey by human agencies that would take care of them in the same manner as were the floats taken care of in the experiment it might be possible that they would reach the intake, but we submit that bacteria leaving the sewers of Chicago could never reach the Illinois River, for the reason that sedimentation would take place and that the float experiment has shown there would be a tendency in the current to make the bacteria flow from the current into the slower water along the sides of the river, where sedimentation would take place and where, according to the evidence heretofore discussd, the bacteria would soon cease to exist.

Counsel state that "when the floats came down the Mississippi River the wind was blowing so as to carry them up stream and regardless of this fact each of the three floats passed on the Mississippi River to the western side and between the intake and Missouri shore." On page 1757 of the

record Prof. Van Ornum states that these floats hugged the Illinois shore and were never more than half way across the river above Alton. That they started with three floats and one was lost below Alton and that from Alton down there were only two. That about two miles above the intake both floats were about fifty feet from the Illinois shore; that one of the floats was pulled out of the water at Chouteau Slough and that witness placed no special import upon the float taken out, owing to the fact, that it had been removed. The witness also states that the floats were affected by the wind. A southeast wind was blowing at the time the floats arrived at the intake. This wind would have a tendency to blow the floats toward the Illinois shore. It would not strike the floats at right angles but very close to it. (1766.)

So upon examining the record we find that only two floats went by the intake and that the witness who made the experiment admits that no weight should be attached to the action of one of the floats for the reason that it was taken out of the water. This leaves but one float to be taken into consideration and according to the witness who made the experiment this float hugged the Illinois shore from Grafton to within two miles of the intake. That this one float drifted towards the Missouri shore is not remarkable, as the witness states the wind was blowing in that direction, and every one of the witnesses, who conducted the experiment in certain stretches of the Illinois River, state that the floats with which they were experimenting followed the direction of the wind.

As to the experiments made by Gardner Stewart Williams referred to by counsel on page 184 of their argument there is nothing but a statement in the record as to Mr. Gardner's conclusions. He was cross-examined, beginning on page 2539 of the record, to which we respectfully invite the attention of the Court. This cross-examination shows that Mr. Williams' statement is nothing but a mere guess.

It must also be remembered by the Court that the ten and one-half days referred to is the time consumed from the south branch of the Chicago River to the intake at St. Louis. A typhoid bacillus would start on its journey in the sewers of Chicago, which owing to the topography of the city, it being very flat, have a very slow flow. Then from the sewers the trip would have to be made through the Chicago River to the south branch thereof, and as the experiments made by defendants show that the life of the typhoid bacillus in highly polluted waters is less than two days typhoid bacilli reaching the canal would have lost their virulence before starting on the journey taken by the floats in the above experiments.

Isham Randolph, the chief engineer of the Sanitary District caused experiments to be made by means of floats to determine the velocity of the water from Chicago to St. Louis. The experiment was conducted by Mr. Crane and showed a time interval of eighteen and one-half days from Lake street, Chicago, to the intake at St. Louis. This experiment was not made at a flood time "not anything like a maximum flood nor was it a low water. It was a full river but not a flood. I think it was above the mean average flow of the river." (Randolph, 6670.)

The time of ten days and a half as ascertained by the experiment [illegible] by complainant was the actual time taken by the float in its passage from Chicago to St. Louis.

"Eight-tenths of the actual surface flow should have been taken in order to get the mean or true velocity. This is unanimously advised by men who have made it a business to test the current of streams. It is what is considered proper practice by men who have made this their business." (Randolph, 6697.)

"Eight-tenths has generally been considered to be the relation between maximum velocity and mean velocity in an open stream.

Q. By whom?

A. Prony was the first man that gave that. Trautwine gives that. It is generally conceded by engineers." (A. S. Crane, 7010.)

If this had been done by Prof. Van Ornum, it would have increased the time of his experiment to over twelve days and that too in the time of high floods on the Illinois River.

As to the chart introduced by Mr. Herring and referred to on pages 184 to 190 of counsel's brief, we believe counsel has a mistaken idea of the facts attempted to be proven by this chart. The object of this chart was to show the relative amount of infection that would be contained in the three rivers upon reaching St. Louis irrespective of any population residing immediately above St. Louis, and this relationship is expressed by the numbers 13, 96 and 107 for the Illinois, Missouri and Mississippi Rivers respectively. (7043.)

In other words it means that taking into consideration the longevity of the typhoid bacillus, as ascertained by Prof. Mills and the relative flow of the three rivers in question, the liability of infection reaching St. Louis is as 13 is to 96 and 96 is to 107, for the Illinois, Missouri and Mississippi Rivers respectively.

For the sake of comparison it is immaterial whether Prof. Mills' table or any other table is made use of, for the reason that the longevity of the typhoid bacillus would be the same in each one of the *three streams*. We therefore do not see why counsel should lay so much stress upon the fact that the table by Prof. Mills is used.

Counsel fail to set out what Prof. Mills' experiment consisted.

Mr. Hering in referring to this experiment, stated:

"The upper diagram on the chart exhibits certain deductions made on the basis indicated in the title with reference

to the longevity of the typhoid bacillus as found by Mr. Miram F. Mills. In the above mentioned report it is stated "to prove whether typhoid fever germs would survive in the Merrimack River water, when at the low temperature of the month of November, long enough to pass from the Lowell sewers to the service pipes in Lawrence, a series of experiments was made by the board by inoculating water from the service pipe with typhoid germs and keeping the water in a bottle surrounded by ice at as near freezing as practicable for a month, and each day taking out 1 cc. and determining the number of typhoid fever germs. The number continually decreased but some survived 24 days:

On the first day there were 6120 germs.

On the fifth day there were 3100 germs.

On the tenth day there were 490 germs.

On the fifteenth day there were 100 germs.

On the twentieth day there were seventeen germs.

On the twenty-fifth day there were no germs." (7003.)

Thus we see that this experiment was made in ordinary drinking water from the Merrimack River at a temperature as close to the freezing point as practicable—not in the sewage polluted waters of the Chicago River and Drainage Canal; sewage pollution as we have heretofore shown being conducive to the quick extermination of this bacillus.

But in this schematic representation of the purification of the three rivers in question it is immaterial what table is used, as indicating the life history of the typhoid bacillus, for the reason that the same condition, so far as the vitality of this germ is concerned, would apply to the three rivers in question. In other words, if the longevity of typhoid bacillus was taken as being less than Prof. Mills' table shows it to be, it would have to be less in the Mississippi and Missouri Rivers, as well as in the Illinois. If its life history was taken

to be more than that indicated by Mr. Mills' table it would have to be more in the Illinois River as well as in the Mississippi and Missouri Rivers. However, the reason for using this table is explained by Mr. Hering, as follows:

"When I had the charts prepared which were introduced in this case by me as a schematic representation of the self-purification of waters, etc., the best information that I was familiar with, regarding the longevity of the typhoid bacillus was that contained in the reports of the Massachusetts State Board of Health.

Since having been engaged on the case I have become acquainted with similar investigations which have recently been made by witnesses in this case, which information is much more exact and practicable and in accordance with actual facts, in my opinion, than the Massachusetts experiments. Had I asked this diagram or this chart to be prepared later I should have used the latter and better information contained in the recent testimony in this case.

As to the longevity of the typhoid bacillus, my opinion is that, particularly with reference to this case, the experiments made by Doctors Russell, Jordan and Zeit would guide my opinion on this question." (7027.)

Mr. Hering, in explaining the diagram, said:

"From an inspection of the diagram it will appear that Chicago is situated, so far as the average flow of water is concerned, about 18½ days from St. Louis. Kansas City, on the Missouri, on the same basis is situated about 6¾ days, and Omaha about 11.6 days from St. Louis. On the Mississippi River, Minneapolis and St. Paul are situated about 15 days from St. Louis on the same basis. The other cities indicated are at a shorter distance." (7003.)

Mr. Hering further stated:

"The distance of Omaha and Minneapolis to St. Louis by water is about 680 miles.

The distance from Lake Michigan to St. Louis by water is about 400 miles.

It will be seen that the Missouri River is the steepest one and the velocity of the water in the river is the greatest. The Mississippi River is the less steep and the velocity would be less great. Therefore, it will take the water longer to flow from Minneapolis to St. Louis than from Omaha to St. Louis, although the distance is nearly the same.

The Illinois River is the flattest of the three rivers and the water has a less rapid velocity." (7002.)

Thus it would be seen that the important question is how quickly infection reaches St. Louis from the watersheds of the Illinois, Mississippi and Missouri Rivers, respectively. In other words, will the gross pollution of the Illinois River reach St. Louis as quickly as will that of either the Missouri or Mississippi Rivers? The question as to the life history of the typhoid bacillus only enters, in so far, as that life history is more or less than the time consumed by the sewage in its journey to St. Louis in either one of the rivers. The table shows that Chicago is 18½ days from St. Louis, Kansas City, on the Missouri about 6¾ days and Omaha about 11.6 days; Minneapolis and St. Paul on the Mississippi about 15 days. It will also be noted that these distances are all *ascertained on the same basis*, that is, by means of the same formula. It is true, as stated by counsel on page 188, that if the time limit of the Illinois River be reduced to ten days instead of eighteen it would result or would have the effect of a town of about 160,000 population immediately above St. Louis. (7016.) But it is not true as stated by counsel, that "The result will be that the sewage from the City of Chicago, containing two millions of people together with the sewage discharged from the cities discharging along the Illinois River, *would result in sufficient typhoid dejecta* passing from those cities to the City of St. Louis equal to the typhoid dejecta

discharged into the river by a city having population of 160,000 people and according to the total per cent. and the testimony of Mr. Hering and Mr. Crane, would result in the establishment of a city immediately above St. Louis having a population of 160,000 people."

See, record, 7016, where Mr. Crane was cross-examined by counsel for complainant on this very proposition as follows:

"Q. Now, assume that the time flow from the mouth of the south fork or south branch of the Chicago River to the City of St. Louis was ten days, how would that effect the result of your determination, and what would be the determination figured on a flow of ten days?

A. It would have the effect of a town of about 160,000.

Q. It would have the effect of a town located upon the Mississippi River, immediately above the City of St. Louis, of about 160,000 population?

A. *According to the chart.*

Q. And as the velocity increased and decreased from the figures which you have given the results, comparatively speaking, would change at the City of St. Louis?

A. They would." (7016.)

It is true that as the velocity of the river fluctuates that the population of this so-called imaginary city would increase or decrease, but counsel forget that it is a poor rule that does not work both ways. The above question was asked on cross-examination. The following question was asked the witness and was the only question deemed necessary to ask said witness on re-direct examination:

"Q. If at maximum flood time the distance in time from Kansas City was 3 days instead of 6.8, as shown by this chart, what would it show?

"A. 230,000. That is the effect of the cities on the Mis-

souri River would be that a city of 230,000 directly above St. Louis." (7018.)

Counsel seem to apply all their zeal on the Illinois River and forget that this chart is a comparative one—making comparisons between the three rivers. They forget that the original basis shown by the chart shows a relation between the three rivers, the Illinois, Missouri and Mississippi, of 13, to 96 to 107; or, to use counsel's own way of putting it, the effect of the Illinois River is the placing of 13,000 population immediately above St. Louis, the Missouri River of a city of 96,000 population, and the Mississippi of 10,700 population. Counsel then say, reduce the distance used in the chart for the Illinois River by half and you will have a city of 26,000 population. They forget that if we reduce the Illinois distance we should also reduce the Mississippi and Missouri distance. We might as well say, reduce the distance used in the chart with reference to the Missouri River and that will show a city of 192,000 population. There is no reason advanced by counsel why one distance should be reduced and not the other, and we submit that there is none.

It is interesting to note, also, in view of the argument of counsel on this very question that counsel for complainant objected to the question asked Mr. Crane on re-direct examination as immaterial. (7018.)

Counsel say on page 188 of their argument:

"This, in our judgment, is a very striking example of the effect of the Chicago sewage upon the waters of the Mississippi River at the intake, based upon the typhoid longevity of Hiram F. Mills, which is the one practically used by all sanitarians and scientists, showing conclusively and strikingly the very marked effect of the waters of the Illinois River upon the Mississippi River, and which demonstrates unquestionably the fact that large quantities of typhoid fever germs pass from Chicago to St. Louis."

The above statement of counsel could well be answered by simply using the words "Missouri" instead of Illinois River. In other words, the table shows "conclusively and strikingly the very marked effect of the waters of the Missouri and Mississippi Rivers, and which demonstrates unquestionably the fact that" if 13 typhoid bacilli reach St. Louis by way of the Illinois River, 96 reach it by way of the Missouri River and 107 by way of the Mississippi.

The fact is, however, that the table does not show that any typhoid bacteria reach St. Louis at all. It simply shows the relative *liability* or *probability* of typhoid bacteria reaching St. Louis by way of the three rivers in question.

As to the chart introduced by Mr. Alvord and referred to on page 189 of counsel's argument this chart is presumed to follow to some extent the chart introduced by Mr. Hering. The plate reproduced on page 7782 of the record has the statement preceding it that the data and methods proposed by Mr. Hering are used, "but with suggestions for corrections as follows: 1st, by using Professor Van Ornum float experiments. 2nd, by valuing the effect of contributory population on the basis of a standard typhoid death rate of 20 per 100,000 living. 3rd, by using velocity of pollution vehicle rather than average of full cross-section of river." (7782.)

This table or chart is of no value whatever in aiding the court in this controversy.

The results obtained by Mr. Alvord are preposterous on their face, the witness stating, as quoted by counsel, that the infection arising at the chain of rocks from the Illinois River would be equivalent to a population of a city of 400,000 immediately above the intake, and in times of extreme floods equivalent to a city of 960,000 immediately above the intake. The very last paragraph of counsel's argument on this subject, on page 190, shows the absurdity of the method invoked

by Mr. Alvord. Although there is only a population of 1,700,000 in the Sanitary District, according to Mr. Alvord's table, using his basis of typhoid death rate at 20 per 100,000 living, would give the Sanitary District a population of 3,750,000, or nearly double the amount.

As a method of comparison, however, whatever basis was used would be immaterial because the same method should apply to the three rivers, a comparison of which is made. If we apply the same principles to the Mississippi and Missouri Rivers the presumption is that proportionally large results will be shown.

On this proposition Mr. Alvord testified as follows:

"Q. By the method that you employed on the Illinois end of this chart, applying that same method to the Missouri and Mississippi Rivers, will you state what the results show?

"A. I have not undertaken to reduce the Missouri and Mississippi Rivers to terms of typhoid pollution at St. Louis in the manner shown by Mr. Hering.

"Q. Why?

"A. Because I did not deem them pertinent to this inquiry.

"Q. The chart which Mr. Hering introduced in evidence showed a comparison between the conditions that obtained on the Illinois, Mississippi and Missouri Rivers, based upon Mill's experiment, did it not?

"A. Yes, sir.

"Q. If you had carried out the comparison contemplated in the chart introduced by Mr. Hering, would the pollution from the Illinois River be as great as the pollution from the Mississippi and the Missouri Rivers, figured in the same manner that you have figured the chart which you introduced?

"A. I am not able to say, not having worked out the data." (7811-12.)

The only significance of Mr. Alvord's chart is that he had a different method of computation than that employed by Mr. Hering, and that this method gave a higher result. He has only applied this method to the Illinois River. The logical conclusion is that if it was applied to the Missouri and Mississippi Rivers it would give the same results, for surely counsel again meet the proposition that it is a poor rule that does not work both ways. For the sake of argument let us say, for instance, that Professor Alvord's method shows an increased infection in the Illinois River of 10 times the amount shown by Mr. Hering's method. It is reasonable to assume that if the same method was applied to the Missouri and Mississippi Rivers the result would be ten times as high as those ascertained by Mr. Hering. The ratio, however, would still be the same, and all that would be necessary to form a comparison would be to multiply 13, 96 and 107 by 10, which would give us 130, 960 and 1,070 as the proportionate amount of infection in the Illinois, Missouri and Mississippi Rivers respectively. Had the comparisons been favorable complainant would certainly have offered in evidence a table applying Mr. Alvord's method to the Illinois, Missouri and Mississippi Rivers instead of limiting it to the Illinois River alone.

In this connection we desire to call the court's attention again to the so-called prodigiosus experiment made by complainants. It will be remembered that a whiskey barrel containing forty gallons of broth culture of bacilli prodigiosus containing over one thousand million bacteria per cubic centimeter was emptied into the Mississippi River just below the mouth of the Illinois River, on September 20, 1900. On September 23rd this organism was alleged to have been found in a sample collected near the Illinois shore, Chain of Rocks, on October 18th, in a sample from the laboratory tap at St. Louis, and on October 24th, in a sample collected near the Illinois shore, Chain of Rocks. Samples of water taken right along after the broth culture was deposited in the river.

On August 31, 1900, this experiment was repeated, with the result that on September 3rd, four days later, this organism was found in a sample collected in the channel in the Mississippi River at Alton.

It must be remembered that samples were taken every hour at the points where the bacillus prodigiosus is alleged to have been found and that, therefore, the time above specified is the shortest time it took the bacteria to travel from the point where the same were deposited to the point where they were alleged to have been found. (781-2.)

Professor Van Ornum's experiment developed the fact that it took six hours and thirty-six minutes for a float to pass from Grafton to Alton, and from Grafton to the intake tower eleven hours and ten minutes. (1742.)

The prodigiosus experiment showed that it took four days for the bacteria to make the journey from Grafton to Alton as against six hours and a half for the float experiment. It will also be noted that of the prodigiosus deposited in the Mississippi River on September 20th, an organism was found, it is alleged, on October 24th, which would make thirty-five days' time consumed by this bacillus prodigiosus in making the journey from Grafton to the intake tower, as against eleven hours ten minutes, as shown by the float experiment.

Let us take, however, the shortest space of time in which the bacillus prodigiosus is alleged to have been found, after having been deposited in the river, which is four days. It took the float six hours to make the same journey. The float, therefore, having traveled sixteen times faster than the bacillus. Making the same comparison with the float experiment from Chicago to St. Louis, the time consumed being about eleven days, as ascertained by Professor Van Ornum, we arrive at one hundred and seventy six days as the time necessary for bacteria to make the same journey, which would be nearly six months.

We submit that either one or the other propositions is right. If the prodigiosus experiment was a success and the organism found was that which was originally deposited in the river, then that experiment is also a true indication of the time consumed by bacteria in making the journey, and the float experiment is shown to be of no value as indicating the time necessary for bacteria to make a journey in the water.

19.

ST. LOUIS WATER SUPPLY IS NOT RENDERED UNFIT FOR DOMESTIC USE BY REASON OF THE OPENING OF THE CANAL, AND IS NOT POLLUTED WITH THE SEWAGE OF CHICAGO AND INFECTED WITH PATHOGENIC BACTERIA AND DISEASE PRODUCING ORGANISMS FROM THE SEWERS OF CHICAGO.

The above heading is a negative statement of the heading of the 19th section of complainant's argument beginning on page 190. The testimony discussed is miscellaneous in its character and is fully answered in this argument under the head of "Typhoid Fever in St. Louis," "Purification of Illinois River," etc., etc.

To avoid repetition we do not again reproduce those portions of this argument that answer the propositions presented by complainant beginning on page 190 and ending on page 230 of their argument.

20.

THE DAMS IN THE ILLINOIS RIVER AND THEIR EFFECT.

It will be noted that Mr. Williams and Professor Sedgwick are again the only witnesses quoted by counsel under this heading, beginning on page 231 of complainant's argument. It

will be noted that both of these witnesses admit that dams have a beneficial effect in the purification of water. They state, however, that in times of freshets there may be danger from scouring. The testimony of witnesses for defendant, including all the Government officials, who have been engaged in dredging the Illinois River for many years, and also of the Fish Commissioners of Illinois, whose business it is to keep constantly in touch with conditions in the Illinois River, is to the effect that no scouring whatever takes place in the Illinois River at any stage.

"The effect of the dams in the Illinois River would be to retard its flow and would increase sedimentation. Sedimentation undoubtedly would be much greater in that portion of the stream outside its banks, where the water was shallow and the current slower." (Hazen, witness for complainant, 2829-30.)

"At times the flow is very much retarded at the dam at Henry, as well as the other four principal dams, which are located in the Illinois River. The retarding of the flow of water at these places serves to elevate the water and back it up stream and overflow the banks of the river and on each side of the river at those places the land is low and thousands of acres of land are inundated by virtue of those dams. Those conditions, in a measure, act as a septic tank for the waters of the Illinois when it is backed up there and held by those dams. I didn't in my examination endeavor to ascertain in what measure and to what extent purification would take place at those points.

"I think I was able to judge from analytical results from the samples taken along the route what effect the dams would have in the ordinary purification processes of the sewage in the water. I think that at times during the year some effect is due to those dams in purifying these waters of the Illinois River to some extent. That effect would be prevalent during

the low water stages of the year, after the overflow had taken place, carrying the sewage laden water over those fields. That is, at the low water stage that part of the sewage that would remain on those fields would not be swept back into the river and of course the low water stages then would facilitate the purification processes." (Teichmann, 1649-50.)

Professor Teichmann, above quoted, is one of complainant's witnesses whose testimony is not quoted by complainant in their argument on this point.

"Before the Canal gets to Joliet it widens out into a lake. The water spreads out there for quite a distance, I suppose 300 yards. Part of it is run through turbines, for power and the other part runs over a little dam. There must be a dam there because there is a water fall. There is some sedimentation in that lake or basin. There must be.

"Assuming that there was a lake at La Salle as large or larger than the one at Joliet, and that the water moves slowly the current at this point, and through this lake or basin, I would say that there would be a sedimentation. We took samples of water at La Salle in 1901, in October and November. I know that the water spreads out in quite a little lake above Peoria. I understand there is a dam at Henry, Illinois.

"Assuming that there is a pond or lake at Henry, there would be more sedimentation there.

"In any stream of water where there are places that we speak of (lakes or basins) there will be sedimentation. At Peoria there is another lake—the water spreads out over quite an area there. The sewage of Peoria is discharged below this lake. In 1901 when I saw this lake at Peoria the current was slow, very slow. There would be considerable sedimentation there. There are three dams across the river now below Peoria. The first is Copperas Creek Dam. I have been up and down it a number of times in a launch. The Copperas Creek Dam backs the water or the water is

backed up a great many miles and it makes quite a stream, navigable for large boats. In the low water season of 1901 I was in it. We had a launch drawing three and one half feet of water and occasionally it would hit the bottom and the water was running slowly at that time, and the current in the river was slow. The water was running over the dam in a good volume.

"There would be considerable sedimentation there. The next dam is at La Grange, below Beardstown. The water backs down behind this dam for quite a number of miles back. The river at the stage I saw it several times was anywhere from 500 yards to a mile wide and the water was deep enough to have the boats run smoothly along up to Beardstown where the water was shallow. There would be considerable sedimentation there. The next dam is at Kampsville. Here the water is again dammed and backs up, the current is retarded and a great deal of sedimentation will go on here in this flowing water." (Ravold, 853-857.)

Professor Ravold is one of the witnesses for complainant and was not quoted by counsel on this subject for the reason as above seen that he also disagrees with Professor Sedgwick and Mr. Williams.

Mr. Fuller is also a witness for complainant. He states:

"The most significant feature of the ponds, *dams* and slack water stretches which are found in the Illinois River, is the low velocity of flow of the water, at times of low stages of the Illinois River. There are a good many days in the course of a year when these velocities at the places above referred to are so low that deposition takes place to a considerable degree, of the bacteria and other matters suspended in the water, and which to a large degree are derived from the contents of the Chicago Drainage Canal." (2619.)

Mr. Fuller further states:

"The dams in the Illinois River, as my memory serves me,

raise the water for a distance of 40 or 50 miles back, and when the water is not at flood tide in the Illinois River the current gets down to less than one-half mile per hour in these back water basins. During those times sedimentation takes place with considerable degree and a great many of the bacteria would go to the bottom of the river. There would be a very small percentage of them, which would not, due to the action of passing boats and wind and those little things, as in all probability occur in the stretches of slack water many miles long, and where the velocity uniformly is very low. When these settling basins extend over surrounding country where vegetation and grass are plenty some of these organisms would get out among the grass and when they got out there it is possible that a freshet would drive them back into the center of the stream, but I think more of them would not go back than would. The percentage removal of bacteria in the settling basins of St. Louis would be in the neighborhood of 75 per cent. (Professor Ravold testifies 95 per cent). A fair general average of the time water has to settle in these basins would be a day and a half. I should think that a current of several miles per hour would remove a considerable portion of bacteria." (2652-3.)

"At the dams in the Illinois River there would be a removal of germs at times when the velocity of flow was small. The germs, when in a state of sedimentation—there would be a dying out among them." (2656-7.)

Mr. Fuller is also a witness for complainant and it will be noted that he states considerable sedimentation takes place when the water is traveling at the rate of two miles per hour and he admits that the back waters caused by the dams in the Illinois River extend back for a distance of 40 to 50 miles above each dam, and that the rate of flow in these back water stretches gets down to less than one-half mile per hour. Professor Sedgwick, complainant's witness, who is quoted by

counsel on page 231 of the argument on this proposition, was cross-examined and testified as follows: (The court will please note that he admits that running water purifies itself, although he is quoted by counsel at another point in their argument as being against this theory):

"I believe that waters of running streams, sewage polluted, purify themselves by the flowing of the streams to a large extent under favorable circumstances. The rapidity of the flow would have something to do with the degree of purification. It is the time factor which comes in and that would be profoundly modified by the rapidity of the flow. Numerous reaches where the flow of the water was extremely sluggish and occasional dams checking the water would contribute to the purification of it. Such reaches and dams would contribute to the purification by other means than sedimentation, by detaining the germs present and thus favoring their dying out if they lay there long enough to die out. Mere detention apart from sedimentation would be a factor in this time factor I have spoken of.

"If near a given river there were numbers of small lakes or ponds which filled up during the overflow or high water of the river and which contributed to the flowing stream of the river, when the water subsided, they would contribute to the purification of the stream in the proportion in which the supposed lakes and ponds afterwards contributed to the current of the stream. In times of flood, it would certainly contribute to the purification of that part of the water which was over lakes. If there was a flood in the Illinois River in which the waters overflowed the banks and spread out in the bottoms which continued for four weeks and in the bottoms there is no perceptible current of the river those portions which stood upon the bottoms would certainly be purified somewhat. They would be purified so far as the sewage is concerned very considerably. I am familiar with the general physical char-

acteristics of the Illinois River from studying maps and talking with men who have been up there. I understand that the bottom lands or the overflowed lands of the Illinois River are very considerable. The fact that the Illinois is a sluggish stream in its overflowed stages, that there are several dams and at times much so-called slack water, that in reaches of the river which are not affected by the back waters of the dams, there is in ordinary stages, in many places, and for long distances, a very slight fall, would aid in the purification of the waters of the Illinois River under ordinary conditions." (2261-2-3.)

Professor John H. Long says there is a dam at the end of the main drainage channel known as Bear Trap Dam, also two dams in Joliet, one at Henry, one below Pekin called Copperas Creek, one at LaGrange, one at Kampsville and one at Marseilles. "These dams in the Illinois River are extremely important factors in holding up the water, retarding its rate of flow, distributing it over a wide area, and therefore of importance in hastening general purification.

"Q. In what way, Professor?

"A. They are important because of the effect which I have mentioned, that they serve to distribute the water over a greater superficial area and retard its rate of flow." (4252-4253.)

Professor Jordan says:

"I regard the conditions of semi-stagnation prevailing in the Illinois River at most points along its course as an important factor in influencing the fate of polluting and infectious matter added to the water of this stream and to the various tributaries. The exceedingly low gradient in the river which has been already referred to and which is further accentuated by dams at various points, retards the progress of suspended matters down stream and affords highly favorable conditions for purification. This is most marked during

periods of low water but at high water the flooding of the low lands and the meadows along the banks of the river also affords opportunity for sedimentation and the retarding influences are still active." (6165.)

Professor E. G. Smith says:

"The dams in the Illinois River are five in number and they would naturally increase the amount of sedimentation of the river because the dam would check the flow of the water and in the checking of the flow suspended matters would tend to be precipitated. The waters are brought to a more quiescent condition, and as a result matters in suspension go down." (6754.)

Professor Russell says:

"A. Taking into consideration the well recognized fact that where a current of a stream is retarded in its rate of flow by an expansion of the cross section of said stream, which condition causes the sedimentation of any suspended matter which may be present in the waters of such stream, it is my opinion that the presence of such expanded portions of the Illinois River would act in a material way in aiding the sedimentation which would occur in the waters of that stream and that such sedimentation would result in the elimination of a large proportion of the total bacterial life, including any disease organisms, if such should happen to be present, that might be present in such waters." (6577-8.)

He also states:

"Q. Will you describe the dams in the Illinois River?

"A. In the trip which was before mentioned I had an opportunity of seeing the dams which have been placed in the lower reaches of the Illinois River, and was able to note the effect these dams would produce upon the physical appearances of the river.

"Q. What effect did those dams have upon the problem of sedimentation?

"A. The rate of flow in the lower reaches of the Illinois River is much slower than in the upper, causing the river to spread out over a wider cross-section. The damming up of this stream through the construction of the dams on the various points of the river, widens still further the body of water in the river, causing slack water to exist for a considerable distance back to the extent that the height of the dam would equal the normal fall of the river. As the fall per mile in the lower reaches of the river is relatively low in comparison to what it is in the upper portion, this damming back of the stream of low water must amount to considerable. This retarded rate of flow of the current reduces the carrying power of the stream, as to the transportation of the suspended material, and thereby produces marked sedimentation. The subsidence of this matter carries down to the bottom of the stream much of the bacterial life which is present in the river, thus purifying the water of the river, of its bacteria as well as relieving it of its suspended load of sediment.

"Q. How is sedimentation in the Illinois River affected by the higher and lower stages of water?

"A. At low water, where the flow is small the result of the dams must produce slack water to a certain extent, causing sedimentation. At high water the load of suspended sediment in the river is a great deal increased owing to the eroding effect of the surface run off on the land. This increase in the amount of the load carried, naturally increases the possibilities of sedimentation, where there are no variations in the rate of flow of the current. As the flow per mile diminishes from the upper to the lower reaches of the river, the current is naturally retarded and thus has a tendency to deposit its load. On the contrary, the larger volume of water found in high water increases the rate of flow and tends to retard this rate of deposition. If the river rises to high stages, where the banks are overflowed, which condition

would easily be possible, as the Illinois River flows through a relatively low plain, the water spreads out over the banks and causes deposition by sedimentation. On the trip taken in September I noted locations where the water was several miles wide. These locations I would consider as giving favorable opportunity for the production of slack water to a greater or less extent and would therefore permit of the marked deposition of the suspended matter which might be present in the stream." (6486-7.)

Professor Mason when asked about these dams stated:

"All of those dams and lakes would have an effect in increasing the opportunity for sedimentation, and such increased sedimentation would have a beneficial effect in the elimination and purification of polluted and infected waters coming into the Illinois River from Chicago.

"An increase in the volume of water in the Illinois River floods the lowlands along the Illinois River. I saw it. It increases the opportunity for sedimentation by overflowing those lowlands, the principle being entirely similar to the one which I illustrated in my morning testimony. Sedimentation would certainly be greater if the volume of water was greater, for the more acreage that is overflowed by such water, the greater number of particles will have a short distance to drop before reaching their final resting place on the soil. All of the dams and lakes in the Illinois River would have an effect in increasing the opportunity for sedimentation and such increased sedimentation would have a beneficial effect in the elimination and purification of polluted and infected waters coming into the Illinois River from Chicago." (6942.)

Professor Jordan on record 6337 states that the dams and slack water basins in the Illinois River materially facilitate the process of sedimentation and also serve to retard the current in not a considerable degree, that in periods of high

water the lowlands along the banks of the river are flooded and that the greater amount of territory flooded the greater will be the opportunities for sedimentation of particles and retarding the flow. (6337-8.)

Mr. Hill says:

"Assuming that there are four dams in the Illinois River, one at Henry, one at Copperas Creek and one at La Grange and one at Kampsville, what effect do those dams have upon the problem of sedimentation?

"A. The dams, whatever the number may be in the Illinois River, particularly in view of the flat slope of the stream bed will create pools corresponding in number to the dams in which sedimentation is bound to take place. Each of these pools acts very like a sedimentation basin when operated upon the so-called continuous plan, that is to say, a sedimentation basin where the water is pumped in at one end and removed at the rate from some other end or point, usually at the opposite end of said basin. I regard the 25 or 26 pools formed in the Schuylkill River between Fairmont dam and Port Clinton, a distance of about 96 miles from Fairmont dam as active auxiliaries in the purification of the polluted Schuylkill water and I believe that if those dams were removed and only Flat Rock dam at Shawmont pumping station and the Fairmont dam at the Fairmont pumping station remained, that the condition of the water coming through our intakes at Shawmont, Belmont, Queen Lane, Spring Garden and Fairmont would be worse than it is now, and the same condition with reference to sedimentation would apply by the maintenance of the dams in the Illinois River, but with greater force by reason of the flatter slope of the stream and the longer the pools formed by each of the dams." (7519.)

It will be noted that every one of the witnesses who testified for defendant on this subject had made a personal e- m-

ination of the Illinois River and the dams in question. It will also be noted that every one of the witnesses testify that the dams would be of benefit at both high or low water.

We fail to find any testimony of Mr. Williams on pages 3324 and 3326 of the record as quoted on page 231 of argument. We do find on page 2534 that Mr. Williams testified that he has never seen the Illinois River.

On page 2535 this witness states:

"Basins are created by those dams to a considerable extent.

"Q. That entire reach of river from Peoria to Copperas Creek Dam would be almost a sedimentation tank, would it not?

"A. At certain stages."

We also suggest to the court that the statement on page 232 of argument of counsel attributed to Mr. Williams' testimony, Vol. 3, page 2386, has reference to testimony of Professor Sedgwick and not of Mr. Williams. See Record, 2386.

That the Illinois River does not scour is shown by the following testimony:

John N. Hipple states that he is a pilot in the employ of the government and is connected with the government dredging machines. He further states:

"The use of the dams in the Illinois River is to back up the water over the bars. These dams retard or stop the flow of the river up to their aprons. Kampsville dam backs up the water as far up as La Grange, 50 miles. La Grange dam backs the water up 50 or 60 miles. Copperas Creek dam backs up the water 40 or 50 miles. Henry dam backs up the water for about 40 miles. (3087.)

"Q. Does the flood in the Illinois River wash out the channel and remove whatever sediment that is in it?

"A. No, sir. (3087.) Bars are formed in the Illinois

River by high water and tributaries, the creeks throw the mud out. It comes down out of the hills. (3088.)

"A flood has the effect to increase the amount of sediment in the back waters or slack waters created at the time of flood." (3089.)

Mr. Hipple also testifies that he has been on the river 30 years.

Here then is the testimony of a witness who has observed actual conditions and knows what he is testifying about, whereas complainant rely entirely on a statement of theoretical conditions as imagined by a witness who has never seen the river.

Frank Tozier states that he is in the employment of the government as engineer and that he dredged for over eight years steady work in the Illinois River. (3101.) He states that the channels that are dredged receive deposits from the tributaries of the river.

"Q. When there is high water in the Illinois River does it wash out the sediment or cause more sediment to settle?

"A. I think it causes more sediment to settle; *there is not enough current in this river to wash out anything.*" (3103.)

"The purpose of putting dams in the Illinois River is to raise the river so boats could run. The dam at Kampsville backs up the water so that it will make at Meredosia about six inches of water. A raise of seven feet here will make it about six inches at Meredosia. It is about 42 miles from Kampsville to Meredosia. La Grange dam is about 7 miles from Meredosia. The La Grange dam was calculated to back the water clear to Copperas Creek lock, but it don't do it. It is 7 feet high. The Copperas Creek dam backs the water up between Henry and Lacob. It is about 70 miles from Copperas Creek dam to Henry dam. The Henry dam used to back the water plumb to La Salle. It is about 40 miles from

Henry dam to La Salle. The dams on the Illinois River are 7 feet high from dead low water." (3106-7.)

Edward Dougherty states that he has been employed by the government on the Illinois River since the spring of 1892 on the dredges. He also says:

"Q. Are you familiar with the Illinois River and have you been upon it in all its various stages from high to very low water? A. Yes, sir.

"Q. What is the effect upon the bottom sides of the channel of the Illinois River of floods in the river, as to the deposit of sediment?

"A. I haven't noticed any serious results from the sediment.

"Q. In times of floods or high water in the Illinois River, is the sediment which has been deposited by the action of the water washed out, or is more sediment deposited?

"Q. In other words, does the river scour? A. No, sir.

"Q. After a flood in the Illinois River, is there more sediment in the bottom and along its banks, or less, than before a flood?

"A. More sediment every time there is a flood." (3124.)

C. V. Brainard testifies on Record 3139 that he has been in charge of all the dredging operations on the Illinois River instituted by the Federal Government in the last 12½ years from Copperas Creek Lock to its mouth. He was examined as follows:

"Q. What is the effect upon the sedimentation in the Illinois River of a flood?

"A. My experience has been that there is no effect on what has already been deposited.

"Q. Does it have the effect to increase the amount of sedimentary matter or material?

"A. Well, that I couldn't say. After floods, after high

waters we frequently find some of our channels filled up. That is usually in parts of the river that are effected by back water from the Mississippi. This may be caused by two reasons, either that the water that is entering the river from the Mississippi is full of sediment which is deposited when the current is slack, or it may be that the water from above in the Illinois River deposits the sediment into the slack water that is formed from above in the Illinois River, by emptying into the back water of the Mississippi, the deposit may be made in either of the two ways.

"Q. Before the opening of the Drainage Canal in January, 1900, did the Illinois River scour and clean itself in times of high water?

"A. I never knew of it doing it.

"Q. Since the opening of the Drainage Canal, does the Illinois River scour and clean itself?

"A. No, sir, no more than it did before.

"Q. Before and since the opening of the Drainage Canal, if sedimentary matter is deposited in the Illinois River, how is it removed?

"A. The only way that it is removed is by dredging it, or some mechanical process; the river doesn't clean itself at all that I have ever been able to find out." (3141.)

James R. Fuller testifies that he is the overseer of the Illinois River crew in the employ of the government and has held that position for 13 years altogether. He was examined as follows:

"Q. What is the effect so far as sedimentation is concerned of a flood in the Illinois River?

"A. It would make some deposit along the banks. At the lower end if we have back water from the Mississippi, it is liable to make deposits in the main channel.

"Q. Does it have the effect to lift up and remove sedi-

mentary matter previously deposited, either in the channel or along the banks of the river?

"A. I have never seen any effects of it.

"Q. In the Illinois River, if sedimentary deposits are made, or occur what is the only means of removing them?

"A. Dredging as a rule, in some form or other.

"Q. Did the Illinois River before the opening of the Drainage Canal scour or clean itself in times of flood?

"A. Not as I ever saw.

"Q. Since the opening of the Drainage Canal does the Illinois River scour or clean itself?

"A. No, sir.

"Q. In either times of flood or in other states of water?

"A. No, sir.

"Q. Since the opening of the drainage canal, if sedimentary matter occurs in the Illinois River, what is the only means of removing it?

"A. Dredging." (3145.6.)

Upon cross-examination this witness was examined as follows:

"Q. You don't mean to say that in times of high water the river does not cut through these bars and deposits and at places form new channels do you?

"A. Yes, sir, that is what I mean to say.

"Q. It doesn't do that?

"A. The river don't cut out channels, don't change a channel form itself; it won't cut a channel through these bars.

"Q. Then the channel you say never changes, either in high or low water?

"A. Not in my experience; it never changes from the river itself, the current never changes. We change the channel

occasionally, dredging. I never saw this river change a channel from the effects of the water." (3147.)

John Weimer testifies that he has been in the employ of the U. S. Government as dredge engineer in the neighborhood of 16 years on the Mississippi and Illinois Rivers.

"The Mississippi and Illinois Rivers do not compare at all as to their channels. The Mississippi river moves and the Illinois River channel remains stationary. The Mississippi River scours and the Illinois River does not. High water in the Illinois River would not scour out the banks of the river. Freshets and tributaries of the Illinois River have quite an effect on the Illinois River in washing the soil off the hills and carrying it into the river. This soil is deposited principally at the mouth of the tributary. When matter is deposited on the bed of the Illinois River I know of no way by which that deposit may be removed except by dredging. High water or current does not change the channel in the Illinois River." (3148-3152.)

Benj. Cole works at the La Grange locks and testifies that the La Grange lock was built with the calculation to back the Illinois River up 50 miles. The dam raises the water 7′ 4″. (3247.)

The above witnesses all testify to the fact that the dredging operations conducted by the government are to cut away bars that form in the channel below the entrance of the tributaries of the Illinois River, that in times of flood these tributaries carry an enormous quantity of foreign matter into the Illinois River, which is deposited below the confluence of the tributary with the river. They also testify that in some instances, where a channel has been dredged out it has again filled up. Witness Weimer stating that when they were just about through dredging below Macoupin Creek a rain came up during one night and the deposits brought down Macoupin Creek during that one night filled up the channel about a foot.

Every witness in this record, including those of complainant as well as defendant, testify that dams have beneficial effect on the purification of water by increasing the facilities for sedimentation in the slack water basins, caused by said dams. The evidence further shows that the Illinois River does not scour, which means that when sedimentation takes place this sediment is not again taken up and carried down the river by freshets, etc. As we have shown elsewhere under the head of "Longevity of Typhoid Bacillus" that typhoid bacteria die quickly in sediment, it will be seen that the effect of these dams is to prevent the passage of virulent pathogenic germs down the river.

But we contend that pathogenic germs do not reach as far as these dams, they being unable to survive the passage as far as Peoria. This proposition will be discussed under the heading as to the "Purification of the Illinois River."

21.

POPULATION OF THE WATER SHEDS OF THE RESPECTIVE RIVERS WITH, AND, EXCLUSIVE OF THE POPULATION OF THE SANITARY DISTRICT OF CHICAGO, TOGETHER WITH THE AREA OF THE DRAINAGE BASINS OF EACH.

The evidence quoted from on pages 232-345 of complainant's argument under the above heading shows that the population referred to is the urban population and not the rural. This is very misleading.

For instance on page 233, Mr. Whipple is quoted as saying that considering cities having a population of 25,000 or over the addition of the Sanitary District to the water shed of the Mississippi makes an increase of about 63%. We do not know whether these figures are correct, but it is immaterial. This testimony would have just as much application to the

question in issue if cities of only 500,000 population or more had been considered, for witnesses for complainant admit that this classification of towns is arbitrary. If Mr. Whipple's idea was carried out still further we might limit cities from which infection is likely to come to those having 1,000,000 population and say that the opening of the Drainage Canal caused all the infection that occurs on the water shed of the Mississippi River.

Professor Sedgwick testifies:

"Q. Well, the computation of percentages as to deaths or as to typhoid fever, based on population, only urban population, and in excess of 4,000, is an arbitrary rule, is it?

"A. I do not exactly understand the question. If you mean is the assumption of 4,000 as a basis of urban population for the purposes of sanitary comparison, an arbitrary one, I should say that it is somewhat so. The basis varies. The United States census for example classifies urban population as cities and towns of 8,000 and more and in different sections of the country, the definition of urban population may vary somewhat, but the estimate of 4,000 as a basis for the estimate of urban population is probably a pretty fair basis.

"Q. At any rate it is an arbitrary basis.

"A. More or less so." (2295-6.)

Mr. Sedgwick is one of complainant's witnesses in this case. This witness on cross-examination testified as follows:

"Q. We will take an unscientific and common rural population, meaning by that a population not in a village or city of 4,000 inhabitants or more, including in rural population, or rather that is not included in cities of 4,000 inhabitants or more. Does not such a population enter very largely into the consideration of all sanitary questions in regard to the pollution of rivers?

"A. It certainly does.

"Q. Doesn't it certainly also enter very largely into the consideration of the infection of rivers?

"A. Yes, sir." (2301.)

It will thus be seen that Mr. Sedgwick admits that the rural population enters largely into the consideration of infection of rivers, yet in the figures given by both this witness and Mr. Whipple, which are the only two witnesses quoted by complainant, no regard is had as to this rural population.

We desire to impress upon the court that the figures given on pages 233-4 of counsel's argument do not take into consideration the population of either of the water sheds in cities having a population of less than 4,000. Mr. Fuller says (Complainants' Argument, 235) that he uses this basis because the amount of population in cities above 4,000, which do not sewer directly into the river, makes up for the population of some towns of less than 4,000, which do contribute sewage directly to the water courses.

If the cities above 4,000 and those below 4,000 compensate each other, why the necessity of making this aribtrary division? Why not take the population as a whole?

Counsel realize that the population and also the drainage area of the Missouri and Mississippi Rivers exceed very greatly that of the Illinois River, and for that reason a method had to be evolved by which they could overcome the real condition.

Mr. Sedgwick is quoted, on page 233 of argument of complainant, as saying that "as a general rule the urban population is very much more dangerous than rural population," and he gives his reasons therefor. This testimony is found on page 2235 of the record.

This statement of Professor Sedgwick is remarkable as showing his inconsistency, for immediately preceding the

above statement he testified about the sources of contamination in certain epidemics as follows:

"A. I think that in the case of Plymouth I did briefly state that the dejecta of a single person who was ill with typhoid fever, and who lived on the bank of the stream supplying the reservoirs, were washed into the stream and delivered to the citizens below, causing one of the most serious epidemics that we have ever known. I did not state, I think, the conditions in the case of the great Lowell epidemic of 1890 and 1891. Those I investigated personally, and briefly described. They were as follows:

"About three and a half miles above the intake of the Lowell waterworks, and on the other side of the Merrimac River there is, as I have stated, a small stream. It is more than a brook; it is a large brook, a stream called Stony Brook. Upon this brook are certain factories, and connected with those factories are certain out houses, some of them overhanging the stream. At one of these in particular, I found that a man named James Larkin had been in the habit of defaecating, while he was a workman in the foundry nearby. He became infected with typhoid fever and spent the greater part of several days, while trying to work,—as he was a poor fellow,—in this overhanging privy. The dejecta fell from him—the excreta fell from him into the brook, and proceeded, as I believed, directly into the Merrimac, and crossing over the river reached the intake of the Lowell waterworks. This was the principal cause, in my judgment, of the great Lowell epidemic, and of the relatively more severe Lawrence epidemic which followed.

"In the case of the New Haven epidemic, a family living upon the watershed had typhoid fever. I think there were two or three cases in the family. Their dejecta were thrown out on the ground near by, and in the thaw which I described yesterday, were washed into the stream.

"Q. How far from the stream were they?

"A. I don't remember just how far; I think they were quite a little distance, perhaps fifty feet or something like that.

"Q. Was that in the winter season?

"A. The typhoid was in the late winter, and the thaw came along, as I remember it, in March, very much as it did in the Plymouth case. This was washed into the reservoir which was ordinarily used—well, it was a regular storage reservoir of the city of New Haven.

"Q. But it went first into the stream?

"A. It went first into the stream.

"Q. And then how far down the stream?

"A. I don't remember; but it was only two or three miles,—something like that,—and from the stream into the reservoir, where it underwent probably a very slight sedimentation, and storage and then passed on to the citizens.

"Q. How many cases were there?

"A. There were 470 cases or thereabouts, at that time from that single infection.

"Q. That was the only known cause of that infection?

"A. That was the only known cause, and was reported by the State Board of Health of Connecticut, to be the explanatory cause of that?

"In the case of Windsor, Vermont, according to the expert employed by the State Board of Health of Vermont, whose results were adopted by that Board as sound, the infection came from a privy about a mile from a storage reservoir, a small storage reservoir—and were supposed to have been washed from the privy into a very small stream,—a mere thread of a stream—

"Q. Well, how was that washed,—by natural causes?

"A. That was washed by rains, by common rains, yes, in the spring; it was at the time of the breaking up of the winter snows and was in the freshet time—from this thread of a stream down into a larger brook, and then into the reservoir, where it was stored for a while, probably not very long, however, and then distributed to the citizens. I myself saw that privy and the local conditions, so that I can speak with some familiarity of that.

"Q. How far was it from the privy vault over to the gully or place—was there water in this little stream when you saw it?

"A. Yes, there was some water in the stream, and the privy was perhaps 500 feet,—the privy was only about 100 feet from the beginning of the small stream, and the wash occurred right across a barnyard into that stream, which practically drained the barnyard, the small stream possibly 500 or 1,000 feet long, ran into a larger stream which went to make up the distance to the reservoir, perhaps a mile or thereabouts.

"At Ithaca, New York, in the recent epidemic it is believed,—it is I think I may say, established, that the epidemic proceeded from pollution upon the watershed of Six Mile Creek. Whether that came from a camp of Italians working on that creek and upon a new reservoir, or whether it came from other workmen upon that watershed is not yet absolutely clear, but everyone is agreed that the epidemic came from fecal matters deposited upon the watershed and washed into the water supply. These are the cases, I think, that I chiefly mentioned yesterday.

"In the Newburyport epidemic to which I referred yesterday, the pollution was, I believe, derived from the regular typhoid fever in the city of Lowell which at that time was excessive; the city of Lowell was full—yes, full of typhoid fever as the phrase went,—and a little larger epidemic than

usual arose. The germs of it were carried down past Lawrence to Newburyport, and showed their effect in Lawrence and in Newburyport.

"In an epidemic which I did not mention yesterday, but which I may mention today, at Zurich, Switzerland, the typhoid fever which visited that city about 1885, was attributed to disturbance of sediment near an intake pipe and a defective filter, by which latter the city was supposed to be protected. A break had come in their intake pipe without their knowledge; their filter was imperfect; it had long been believed to be that, and the disturbance of some sediment near the intake pipe was followed by an epidemic of typhoid fever in Zurich which has been attributed by sanitarians generally to that cause—that source.

"In a case which occurred in Catherham, England, in 1879, a pollution by one workman infected the water supply so that several hundred cases of typhoid fever appeared at a place in which it never had been before; that pollution taking place near the source, in a well which they were digging for additional water supply. The presence of workmen upon a watershed is a constant menace to the purity of water supply, and in addition to the population which may pollute the water, is recognized as a very serious menace. I have known within my own experience, of two cases of that kind where the temporary addition of bodies of workmen to a watershed, typhoid fever having appeared among these workmen, was regarded as a distinct and very serious danger to the communities using the water below. Two of these were within my own experience.

"In the building of the great reservoir at present, of the Metropolitan Water Supply at Boston, extraordinary pains are taken with the workmen on the watershed to see that they shall not pollute the supply, and in general, whenever any filth or fecal matter or sewage or drainage pollution or

contamination or anything of that sort is added to a water shed in such a way that it may find access to the streams,—I will say readily find access to the streams,—it is everywhere regarded as a serious threat to the health of the people below, who use that water.

"I don't know that I need to take up your time with any more cases."

This testimony shows that all the leading epidemics known in literature were caused by rural infection. It will be noted that this witness states above:

"The presence of workmen on a water shed is a constant menace to the purity of water supply, and in addition to the population which may pollute the water, is recognized as a very serious menace."

If this applies to workmen on the water shed why should it not apply to the rural population resident on the water shed?

It will also be noted that this witness states that the faecal and infectious matters causing the majority of the epidemics referred to were washed by common rains from the water shed into the streams used as a water supply.

As to rural infection, Professor Jordan testifies as follows, beginning with record 6273:

"Q. Will you distinguish between the effect of an urban and rural population upon a water shed?

"A. I take the question to imply that the sewage and drainage from such urban and rural communities are discharged without purification or special treatment into the streams upon such water shed. It is now true that most urban communities are provided with sewers and it is also true that such sewage often passes directly into the nearest water course. The amount of pollution added directly to a river by an urban community is therefore considerable.

"In the case of a rural community or of isolated dwellings or scattered farm houses the waste matters due to human life and habitation are not added as a rule so directly to the stream, although, as is well known, in most parts of this country it is a common custom for the outhouses and privy vaults to be located on or near the banks of small brooks or rivulets.

"On the whole, however, the total amount of organic matter added to a water course by an urban community provided with sewers is greater per capita than the amount of similar organic matters added by a rural population of the same dimensions.

"Q. Is typhoid fever more prevalent in urban than in rural communities?

"A. No, sir—just the reverse is true. Typhoid fever is a rural rather than an urban disease.

"For example, the death rate from typhoid fever in the thinly populated 'Adirondacks and Northern' district of New York State in 1900 was 3.9 per 10,000, as compared with 2.0 in the so-called maritime district, including New York and the population thickly settled along the seaboard. This is only one of many instances that might be given as to the greater prevalence of typhoid fever in the country than in the city.

"As confirmation of this statement I may quote from an article on typhoid fever in the Journal of the American Medical Association for January 9, 1904, by Dr. John S. Fulton of Baltimore.

"According to the figures given by this authority, derived from the 12th census of the United States, typhoid fever is conspicuously a rural disease. He says: 'When we examine the rank of typhoid fever among all the causes of death we find that rural typhoid fever is credited with 62 in every 1,000 deaths, as against 38 per 1,000 from urban typhoid.'

This writer gives elaborate diagrams and tables which bring out with great clearness the fact that typhoid fever at the present time in the United States is a rural rather than an urban disease.

"Q. Is the danger from a rural population to be given slight consideration by a sanitarian or an epidemiologist?

"A. It is my opinion that the danger from a rural population can by no means be ignored by any sanitarian or epidemiologist who wishes to take into account all data bearing upon questions of the spread and transmission of infection.

"Q. Is the rural population on the water shed an important factor to be considered in passing upon a water supply of a city using river water for domestic and drinking purposes?

"A. In my opinion it is a very important factor, since serious infection of a water course may be due to rural infection. I am aware that the significance of rural population in this connection is not always assigned the importance which in my opinion it deserves.

* * * * *

"Q. Do you know of any important typhoid epidemics in which infection has come from the rural population?

"A. The most extensive localized epidemics of typhoid fever in this country, namely, those at Plymouth, Pa., Ithaca, N. Y., and Butler, Pa., have been caused by infection from a rural population.

"The epidemic at Lowell, Mass, was also due to the infection of the Merrimac River by isolated cases of typhoid fever and not from a population provided with sewers.

"Q. Are there any reasons why infection from the rural population is to be specially feared?

"A. It seems to me that there are at least two reasons why infection of a water course by a rural population is especially to be feared.

"Q. What are those reasons?

"A. The first of these is that, on the whole, disinfection of the dejecta and urine is less carefully and thoroughly carried out in rural communities than in urban, so that in a given number of cases of typhoid fever a larger proportion will be improperly cared for in rural communities than in cities.

"In the second place, the storing up or accumulation of infectious material from typhoid cases may result in a very heavy infection of a water course, since the discharges that have collected during the whole course of a case of typhoid fever may be washed, all at once, by a heavy rain into a water course.

"Still another reason and one that I believe to be very important is that when typhoid bacilli are added to a stream in the sewage of an urban community, they are accompanied by a large amount of organic matter and a large number of saprophytic bacteria.

"In rural infection, on the other hand, the bacilli from a single case of typhoid fever may pass into a stream unaccompanied by any considerable amount of organic matter. The dilution with pure water of this relatively large number of bacilli and their mingling with the waters of a large stream constitute a peculiarly dangerous kind of infection. The competition of the sewage bacteria in such a case is not nearly so great as in the case of typhoid bacilli passing into the sewers of a large city.

"It has been shown previously that typhoid bacilli will live longer in relatively pure water in the presence of a relatively small amount of organic matter than in a polluted water, charged with the sewage of a great city.

"For these reasons, therefore, it is my judgment that the infection from a rural population should not only not be ignored, but should be especially feared." (6273-7.)

Professor Russell when asked about rural infection testified as follows:

"In view of the fact that the urine of typhoid patients often contain bacilli in great abundance, and in view of the fact that this material is not ordinarily looked upon as dangerous, and therefore is frequently thrown upon the surface of the ground, and in view of the fact that in rural communities greater carelessness prevails in regard to the disposition of this excreta, and even solid material, than would be true where special systems of sewage disposal were present, it naturally follows that the liability of the population to the infection of the river is added to considerably from the rural population.

"It is a well recognized fact from statistical evidence, that the percentage of infection designated as typhoid fever mortality at least is not less common among the rural population than in urban communities.

"There are a considerable number of typhoid epidemics which have been reported in which the sources of pollution have been traced specifically to infection arising from the rural population. Among these may be mentioned the Swiss case, which is found in many text books, in the small City of Lausanne, Switzerland. The case mentioned by Gaffky of a troup of soldiers in the barracks of Wittenburg, Germany.

"The best known case here under American conditions is that which occurred in the small City of Plymouth, Pennsylvania, in 1884. The epidemic of typhoid fever in Lowell was rural in origin, and the very recent epidemics which occurred in Ithica, New York, and also one which was just passed at Butler, Pennsylvania, where in each instance over a thousand cases of typhoid fever occurred, are both of them undoubtedly attributed to their origin to infectious matter, which would be designated as rural.

"Q. Are there any reasons why the infection of the rural population is to be especially feared?

"A. On account of the carelessness which prevails in the disposition of the dejecta and also the fact that disinfection of this waste is not carried on so frequently in the country as it is in the city communities, I would consider that these were features which render the conditions which would obtain in the rural population a matter of especial danger." (6543.)

Professor E. G. Smith testified as follows:

"The liability of pollution and infection of the river from the rural population is very decided. The relation of the rural population is one of the important questions to be considered always in making up our studies of the epidemics of typhoid fever in any given locality. Often epidemics of some of our largest cities have been traced to causes outside of the city in rural districts. Infection from rural population is a very common cause of epidemics. In the case of the epidemic at Plymouth, Pennsylvania, Butler, Pennsylvania, and Ithaca, New York, the sources of epidemic were traced to pollution from the rural population. Then, in my own experience, I am sure that the prevalence of typhoid in Denver is due to conditions outside of the city, either up the Platte River or up Bear Creek Canon." (6768.)

According to this evidence rural infection is more dangerous than urban infection and should be taken into consideration.

Mr. Whipple's and Professor Sedwick's method of eliminating the population on the three water sheds resident in cities of less than 4,000 population is an ingenious way of making it appear to the court that the opening of the Drainage Canal has added enormously to the water shed of the Mississippi River. This can only be done, however, by making a comparison which involves the elimination of the rural population as above set forth. Complainants use this method of comparison because it is more favorable to them, not because

it is based on sound reason and actual conditions. Mr. Sedgwick himself on cross-examination admits that "the rural population enters largely into the consideration of the infection of rivers." (2301.)

We do not discuss this portion of complainant's argument for the reason that we believe it material, but because the statements therein contained might lead the court to a misapprehension of the facts. We insist that it is immaterial what percentage of population is added to the Mississippi watershed if the sewage from that population, when it reaches St. Louis, has been stripped of its injurious or infectious qualities. Hereafter in this argument we will discuss this question and show to the court that the sewage from the population resident in the Sanitary District is entirely freed of pathogenic bacteria and reduced to an even more potable condition by the time it reaches the Mississippi River than is the Mississippi River itself. However, as counsel have entered upon a discussion of the subject of the population and drainage area of the respective watersheds we desire to present here some of the statements of witnesses in this regard.

As to the drainage areas Mr. Ravold says:

"The watershed of the Missouri River embraces 530,000 square miles. The Mississippi River I cannot give. Of the Illinois River it is 27,914. The drainage area of the Illinois River as compared with the drainage area of the Missouri is very small. The drainage area of the Illinois as compared with Missouri and Mississippi combined is very small." (83-4.)

Professor Whipple, one of complainant witnesses, testifies on page 2041 of record as follows:

"From memorandum that I have read, according to the 11th census of the United States, the drainage area of the Missouri River was about 527,000 square miles and accord-

ing to report of chief of weather bureau for 1896 and 1897, was about 527,150 square miles; the drainage area of the Mississippi River above Grafton according to 11th United States census was about 143,512 square miles and according to report of chief of weather bureau it was 126,750 square miles, while the drainage area of the Illinois River I have already given. Making a total for the three watersheds of the three rivers mentioned, and excluding the I. & M. Canal and Drainage Canal, 699,525 square miles according to the United States census and 693,050 according to the chief of weather bureau.

"Q. I will get you to state if it is not a fact that in this area of these three rivers, that you have mentioned, that is within these drainage basins, exclusive of the Chicago River, the I. & M. Canal and the Drainage District, if the population according to the United States census was over 12,000,000?

"A. I don't know as I haven't made any estimate of such a population. If we assume there are 12,000,000 inhabitants living upon the watershed of the Missouri River and the Mississippi river above Grafton, and the Illinois above Grafton, exclusive of the population living within the Chicago Sanitary District, and if we assume that there are living within the Chicago Sanitary District 1,639,456 inhabitants, and if we assume that the amount of sewage from each individual is the same as the amount of sewage from every other individual upon the three watersheds mentioned and within the Sanitary District, and if we assume further that all the sewage from all these individuals mentioned as living upon the three watersheds, and within the Sanitary District empties into the streams mentioned, the amount of sewage contributed by the inhabitants of the Sanitary District of Chicago would be about 13.6 per cent. of the amount of sewage contributed by the 12,000,000 population dwelling upon the three water-

sheds mentioned, exclusive of the Sanitary District." (2041-5.)

Professor Whipple is the witness whose testimony is quoted on page 233 of the argument and the above facts were brought out under cross-examination.

As to the drainage area of the Illinois River Professor Whipple testifies on record page 2032 that a memo from the 11th United States census states it to be 29,013 square miles and another from the chief of the weather bureau which states it to be 29,150 square miles. In other words the drainage area of the three rivers combined is 699,525 square miles, of which 29,013 should be attributed to Illinois. This would be about 5% exclusive of the Sanitary District.

Taking total population as a basis we have 13.6% of the population of the three drainage basins applicable to the Sanitary District of Chicago. In other words, the addition of the Sanitary District to the watershed of the Mississippi instead of doubling the population of the watershed as testified to by Mr. Whipple or adding 63% to the population as testified to by Professor Sedgwick, adds only 13.6% to the population of that watershed.

Tributaries of the Illinois River and Their Sanitary Condition.

As to the above sub-head on page 235 of the argument of counsel, this subject will be discussed under the heading of "Purification of the Illinois River." Suffice it to say here that counsel are laboring under a misapprehension when they state "The testimony on both sides of the case shows that the sanitary condition of the tributaries of the Illinois River is far better than the sanitary condition of the Illinois River itself."

Every witness for the defendant testifies that the Illinois River by the time it reaches Grafton is in as good if not a

better sanitary condition than are the majorities of its tributaries.

Professor Teichman on page 1175, which is quoted by counsel to sustain their contention, testifies that he draws his conclusions from the fact that there are lower chlorines in the tributaries of the Illinois than there are in the Illinois River proper. He admits that they all show pollution from free ammonia, nitrites, etc., quite high. A reference to this page will show that the only fact relied upon for this statement is the low chlorine. He states:

"The fact that the chlorines are very low would demonstrate from the standpoint of sewage pollution that these tributaries are considerably less sewage polluted than the Illinois River proper."

It will be remembered by the court that chlorine is a stable chemical constituent of water, in other words, the amount of chlorine is not reduced after purification of the water by natural causes. If the water starts from Chicago and enters into the Drainage Canal with a high percentage of chlorine in connection with the other chemical constituents, which indicate sewage pollution, the water may purify itself of the other constituents, but the chlorine will not correspondingly decrease in amount. No chemical change takes place in chlorine. The quantity contained in water can only be changed by dilution, evaporation or some such physical change. It is therefore to be expected that the same amount of chlorine will be found at Grafton as is found at Peoria. It is a harmless constituent of water and non-injurious to health. The fact that there is a larger amount in the water of the Illinois River at Grafton than there is in the tributaries of the Illinois River, taking chlorine as the only test, simply indicates that the water at Grafton was at one time more sewage polluted than are the waters of the tributaries of the Illinois. The other chemical constituents, however, show conclusively

that the water has recovered itself and as we will show hereafter is purer than the waters of its tributaries.

As to this very question Professor Jordan testified as follows:

"Q. Does the presence of chlorine in the water of a river in the absence of the other chemical ingredients or constituents of sewage indicate of itself the presence of sewage pollution?

"A. In my opinion the presence of chlorine under those conditions would be absolutely devoid of sanitary significance. It would be possible for a stream in the condition that the Illinois River was in at Kampsville, to be passed around the world several times in a closed conduit, consuming years or decades in the process, without altering materially the amount of chlorine in the water, although it is my judgment that, supposing the water were at the outset injurious to health, in the course of such a passage and in such a time, it would become entirely free from any injurious qualities it might have originally possessed." (5969.)

The same answer applies to the testimony of Professor Keiser on page 1143 of the record.

As to the actual condition of the Illinois River as compared with its tributaries we will not weary the court with a repetition of the argument which will be found elsewhere on this particular subject.

22.

"THE PHYSICAL CONDITION OF THE ILLINOIS RIVER BEFORE THE CANAL WAS OPENED COMPARED WITH THE CONDITIONS SUBSEQUENT TO THE OPENING OF THE CANAL."

It is true that prior to the opening of the canal the current of the Illinois River was slower than it has been since

the opening. It is not true, however, that "since the opening of the canal the river has not purged itself of the polluting material deposited in it, not having sufficient time to oxidize or destroy the material deposited in it. It has passed out of the Illinois River at its mouth into the Mississippi," as quoted by counsel on page 236 of their argument. Neither does the testimony of the witnesses cited on that page sustain the above contention. These witnesses testify that the current is now faster and there is less of the green scum on the river. We will show, however, in another part of this argument that notwithstanding the increased current the sewage coming from Chicago through the Drainage Canal has become harmless by the time it reaches Peoria. None of the witnesses quoted by counsel under this heading testify as to the facts contained in the above quotation. On the contrary the testimony of these lay witnesses has been collated under a separate head in this argument of defendants and shows conclusively that all of the witnesses from Grafton to Morris testify that in their opinion the water of the Illinois River is better since the opening of the canal than it was before.

As to the pollution discharged into the Illinois River at Peoria and Pekin, referred to on page 238 of their argument, the chemical and bacterial analyses show the amount thereof. This will also be discussed under another heading. The results obtained in the examination of the river, bacteriologically and chemically show a great amount of pollution entering at this point.

The results of these examinations in addition to the lay testimony also show whether the river has improved or not at these points.

We do not understand what is meant by counsel when they state on page 239 of argument, "So the increase of typhoid fever due to the increased pollution cannot under these cir-

cumstances be attributed to Peoria and Pekin." They then say "See testimony of C. F. Barstow, Vol. 4, page 3587."

This witness does not testify to any increased or decreased typhoid fever due to the pollution in the river from Peoria and Pekin. In fact, the statement above quoted and the reference made to the testimony of this witness have no relation to each other as the court will find on examining page 3587 of the record.

23.

THE VELOCITY OF THE ILLINOIS RIVER HAS BEEN INCREASED SINCE JANUARY 17TH, 1900, DUE TO THE OPENING AND OPERATION OF THE CHICAGO DRAINAGE CANAL, BUT THE INCREASE DOES NOT CONSTITUTE AN ADDED DANGER TO THE PEOPLE OF ST. LOUIS AND MISSOURI.

It is admitted by defendants that the opening of the canal has increased the flow of the Illinois River, but this increase does not constitute an added danger to the people of St. Louis and Missouri. It will be noted that the only witness quoted by counsel under this heading is Professor Sedgwick. Under the heading "The Purification of the Illinois River," this proposition will be found discussed and it will be there shown that notwithstanding the increased volume of the river the dilution of the waters of the Illinois with the pure water from Lake Michigan has benefited the Illinois River water and that the elimination of pathogenic bacteria and other infectious materials takes place now just as it did before the opening of the canal. We will not burden the court by repeating that argument here.

24.

THE INCREASE IN TYPHOID FEVER IN ST. LOUIS SINCE 1899 HAS BEEN DUE TO INFECTED WELLS OR MILK.

We desire to call the court's attention that Professor Sedgwick is again the only witness quoted by counsel under this heading, beginning on page 240 of complainant's argument. On cross-examination he stated that he did not know whether these wells were located in the neighborhood of outhouses but that he had no doubt that some of them were. (2341.)

He further said:

"Q. How many wells in the City of St. Louis have you investigated personally, that privies drain into? A. None.

"Q. How many privies in the neighborhood of those wells, within these three years, have received the excreta of typhoid patients? A. I don't know.

"Q. How many people living in the houses where these wells are located and drinking the well water, have contracted typhoid fever from them, if you know?

"A. I have no means of knowing. (2343.)

"Q. And in the absence of knowledge upon those three propositions, do you claim as an expert sanitarian, that your conclusions in answer to my former question were established beyond a reasonable doubt? A. I do.

"Mr. Todd: If conditions existed in any of the wells of St. Louis where fissures appeared, permitting the contamination of privies to enter the wells, such as you have indicated in part of your answer, have you investigated to ascertain whether that condition obtains or not?

"A. I have not. If that condition should obtain, then in my opinion, it would be a serious menace to the health of the people drinking that water. I do not know whether in

the three thousand wells in St. Louis, that condition obtains in one or more wells." (2345.)

It will be noted at top of page 242 of complainants' argument counsel say that district No. 6, having only 311 wells, had 145 deaths while district No. 7, containing 1877 wells had 78 death. This we contend shows that the wells must have been the cause of the enormous number of deaths in district No. 6, for why should district No. 6 have twice as many deaths as district No. 7, if the population in both districts were drinking city water?

Counsel's assumption that there ought to be more deaths in a district containing more wells than another would be sound one if all the wells were infected. It is not assumed by defendants, however, that all the wells are infected, but we contend that the high death rate from typhoid in district No. 6 as compared with the death rate in district No. 7 can be attributed to no other cause but that some of the wells in district No. 6 were infected and caused the high typhoid death rate.

Counsel then quote Professor Sedgwick as saying at the middle of page 242 of argument, "There is absolutely no reason to suppose that a different condition prevails in the wells of the City of St. Louis since January 1, 1900, than that which had prevailed there for years before." Let us then examine into the conditions prior to the opening of the canal.

Mr. Randolph was examined as follows, beginning on page 6685 of the record:

"Q. Will you turn to page 12 of the Seventeenth Annual Report of the Health Commissioner of St. Louis, for 1893-4, and read what is said under wells?

"A. 'WELLS. The examination by chemical tests of water taken from surface wells in different parts of this city progressed memorably during the year, and a number of these

sources of contaminated water supply for households have been condemned. The standard of allowable impurity established for the purpose of this undertaking is quite liberal, but even as thus measured, very many wells were found to contain water utterly unfit for human consumption.'

"Q. Will you turn to page 63 and read from the annual statement as found in the Seventeenth Annual Report of the Health Commissioner of St. Louis for 1893-4, what is said there about wells?

"A. 'Number of samples of well water analyzed 2. Private wells, 239; b. public wells, 8. Number of impure wells reported for condemnation: a. private wells 41, b. public wells 5.'

"Q. Will you turn to the bottom of the same page and read what is said in regard to the analysis of wells, etc.

"A. 'Reviewing this work I respectfully venture the following remarks and suggestions:

"'1. The analyses of well and cistern water were based strictly upon the standard adopted in the month of September, 1893, by the commission appointed by the honorable board. Although the analyses of wells thus far made do not represent every ward in the city, the comparatively large number of wells found to be impure, averaging about 1 out of 5, fully justify the vigorous continuation of these examinations. The Sanitary Division has already presented a list of nearly 3,000 wells and with proper facilities provided by appropriations I expect to be able to analyze the larger part of this number during the present fiscal year in addition to the other expected work. The principal object of these examinations of wells being sanitary, bacteriological investigations should be included wherever the indications call for them. The last annual appropriation did not provide for the purpose of bacteriological apparatus, therefore such examinations could not be made.'

"Q. Will you turn to page 215 of the health reports of the 18th Annual Report of the Health Commissioner for May 31, 1895, and read under the head wells contaminated, total number of wells.

"A. 'Total 59 wells.'

"Q. Will you turn to page 65 of the same report and read what is there under wells?

"A. 'Wells. 59 wells have been condemned by the Board of Health and very few have been closed. The standard which was established by the Board of Health in relation to wells should be legalized by the Municipal Assembly. Where city water is on any premises and where it is desired to retain the well for stock or washing purposes, a permit to do so should only be given under certain binding conditions—the assembly should enact the law.'

"Q. Will you turn to page 204 of the same report and read the table showing the total number of wells by wards in the City of St. Louis, April 1, 1895?

Ward.	Public Wells on Street.	Total Number of Wells in Ward.
1	6	19
2	2	20
3	2	57
4	10	148
5	23	291
6	46	298
7	14	541
8	11	191
9	14	168
10	9	256
11	10	140
12	26	468
13	37	435
14	9	58
15	9	150
16	15	199
17	8	40
18	29	348
19	10	58
20	3	10
21	13	52
22	5	17
23	16	147
24	13	46
25	6	116
26	57	210
27	30	284
28	4	79
Total	437	4848

"Q. Will you turn to page 66 of the 19th Annual Report of the Health Commissioner for 1895 and 1896 and 1897, that part of the report of the meeting of August 1, 1895?

"A. A communication was submitted by the Health Commissioner in reference to the report of the City Chemist on analyses of the water from seven wells, the water of which is impure according to the standard adoption by the Board of Health some two years ago. The communication was made the basis of the following resolution, which on motion duly seconded was adopted:

"'Resolved that hereafter the City Chemist shall make no examinations of well or cistern water unless by special direction of the Health Commissioner.'"

This shows that one out of five of every well examined in St. Louis was found to be contaminated, and although fifty were condemned, "very few have been closed," and the City Council passed a resolution providing that thereafter no more examinations should be made.

Mr. J. W. Hill testified:

"It is, I believe, a common opinion of sanitarians to-day, and it is certainly my opinion, that an open well is not a safe source of drinking water, in an old and well built up urban community, by reason of the fact that soil in due time will become polluted with the wastes from privy vaults and cess pools, and that pathogenic bacteria and perhaps other objectionable matter from such cess pools and vaults made by the ordinary means find a way into the well, and render such water unfit for drinking purposes." (753-6.)

Prof. Thayer said:

"Q. Assume that in the City of St. Louis in 1895 there were in the neighborhood of 4,800 wells, and assume further that the board of health of the City of St. Louis authorized an examination of those wells by the city chemist and after an examination of about 50 of those wells, all of which were found to be contaminated, and were condemned by the city chemist, that the board of health passed an order instructing the city chemist to stop the examination of city wells until

further ordered, and assume that the water from those wells was used by the citizens of St. Louis, would the presence of such a number of wells in a city in your opinion have any effect upon the typhoid conditions of such city?

"A. Yes, I should think that the chances were that they would; that such wells would be a menace to the health of the city and that it would be very possible that certain of the wells might become infected and serve to spread the disease.

"Q. Where typhoid fever is due to infected water supply, how does it manifest itself in its vital statistics?

"A. In those cases in which infection of water supplies have been definitely or fairly definitely proven, it is always, I think, to my knowledge, manifested by an explosive epidemic.

"It is common to assume in cities, such, for instance, as the City of Baltimore, where we know our supply is open to contamination, it is common to assume that cases are dependent upon the water supply, but as a general rule where it can be proven that the water supply going to a whole city is infected there is an explosive outbreak and it seems to me it would be very difficult to prove the instrumentality of a general water supply to a city in producing typhoid fever unless such an epidemic occurred. I should expect with a seriously infected water supply such an epidemic to occur." (7465.)

In this connection it might be well to state that the alleged increase in typhoid fever in St. Louis after the opening of the Canal was a gradual one, as will be more fully shown in the discussion under the head of "Typhoid Fever."

Professor Mason said:

"Assuming that on April 1, 1895, the total number of wells in St. Louis was 4,846, and that the city chemist after an examination of 59 of those wells, condemned them as being unsanitary and assuming further, that in August, 1895, upon the report of the city chemist condemning seven more of these wells, the Board of Health of St. Louis passed a resolution

to the effect that the city chemist should make no further examination of the wells in question, and since 1895 none of these wells has been condemned, I believe that the water of those wells was responsible for a portion of the typhoid fever in St. Louis, because I am a believer in greater danger coming from a polluted well water than from the water of a polluted stream.

"My reasons are based upon data such as that which I gave in answer to a previous question, showing that the death rate of well water epidemics was greater than that of stream epidemics, and showing that the intensity of fever from well water epidemics was greater than from stream epidemics." (6938.)

No reasons are given by Professor Sedgwick for his statement on the bottom of page 242 of complainant's argument.

This statement was made in answer to the following question:

"Q. If such a well should exist and be connected with a dairy where the water from the well was used in diluting milk, could not that have spread the disease of typhoid throughout the city if the milk was delivered to different houses and consumed by the people?"

If milk became infected with typhoid germs that came from a well, why could not the disease be spread among the consumers of that milk, whether they were all resident within one ward of the city or were distributed over the entire city? For instance, why could not the high mortality from typhoid fever in District No. 6 be attributed to typhoid fever contracted by persons living in that district who had consumed milk delivered to them by a dairyman, whose well had become infected with typhoid germs? Surely a person resident within this district, other conditions being alike, would be just as susceptible to the disease as a person residing at any other part of the City of St. Louis.

25.

THE DOCTRINE OF SELF PURIFICATION OF STREAMS DISCUSSED.

Complainants argue this subject beginning on page 243 of their argument.

Under this heading we will only follow counsel's argument so far as it relates to the general proposition of the purification of streams, and will discuss elsewhere the specific proposition of the self-purification of the Illinois River. Under that heading we will show that no pathogenic germs from the City of Chicago remain alive in the water of the Illinois River by the time that river reaches the Mississippi River.

It is true that the character of the flow and the amount of pollution and infectious material discharged into the river governs largely the life of disease producing germs that may find their way into the river. It is by taking into consideration all these elements which are peculiar to the Drainage Canal and Illinois River that the conclusion is arrived at that that river purifies itself of the infectious material placed therein by means of the Chicago Drainage Canal. We do not desire to repeat that part of the argument at this point, as we do not desire to burden the court with more matter than is actually necessary.

According to the heading of this part of counsel's argument we would naturally expect a discussion of the doctrine of self-purification of streams. All we find, however, is a series of statements by Professor Sedgwick, who is the only witness cited by counsel under this head, because as we will show he again stands alone on this proposition.

This witness states on page 243 of counsel's argument that: "It was formerly believed by experts that running water readily purifies itself. That belief has been abandoned,"

On the very next page he contradicts himself by saying: "Nevertheless, there is a large measure of self-purification of streams. There is at times in certain streams especially a large measure of self-purification."

Counsel for complainant are forced to take the same inconsistent position, for on page 246 of argument will be found the following heading, "Facilities for self-purification in the Illinois River were better under the conditions existing prior to opening of Canal than under the conditions which have existed since the opening," thus admitting that self-purification takes place.

Professor Sedgwick is again called into service by complainant to sustain this contention. His testimony, however, was simply to the effect that there is a swifter current in the Illinois River now than there was prior to the opening of the canal.

The generalities indulged in by Professor Sedgwick have no bearing upon the question of whether the Illinois River is subject to self-purification. This witness admits, as quoted on page 243 of argument, that "running water under some conditions might very largely and possibly even altogether purify itself from infectious germs, but these conditions would have to be very unusual, and so unusual so as to be practically theoretical or virtually theoretical." He does not state that such conditions do not exist in the Illinois River.

We will first show to the court that there is such a thing as self-purification of streams and that this self-purification is taking place to-day the same as it did years ago. Of course, it is true that the physical condition of the water course, the amount of pollution, the character thereof, the speed of the current and other things must be taken into consideration.

In this connection it must be borne in mind by the court that infection is caused by pathogenic bacteria and that the

elimination of bacteria means the elimination of disease producing substances.

Professor Jordan says:

"From all the tables and analyses submitted by me in evidence in this case, assuming that by practical purification is meant the death of typhoid bacilli, in my opinion this purification has occurred before the flow of the Illinois River reaches Averyville. The exact point must vary somewhat with the rate of flow, temperature, number of bacilli introduced, concentration of sewage, etc. The question of self-purification of running streams has been given great attention in Europe and in parts of this country. I have read the statements on this matter by the leading authorities on water supply and river water, published in English, French and German."

He further says:

"Q. What statements are there regarding the progress of sef-purification regarding running waters?

"A. I have here a quotation from a book entitled 'Water and Water Supplies,' by Dr. John C. Thresh, Medical Officer of Health to the Essex Council: Lecturer on Public Health, King's College, London, Editor of the Journal of State Medicine, Hon. Sec. Incorporated Society Medical Officers of Health: Fellow of the Institute of Chemistry, Member of the Society of Public Analysts, etc. This book is one of the best known and most authoritative treatises in the English language on water supply. The statement follows: 'The balance of evidence is decidedly on the side of those who uphold the theory of self-purification, and the diverse conclusions arrived at by different observers can be accounted for by the varied and often imperfect character of the experiments, and by the diverse conditions which obtain in different streams. That river water, grossly befouled by sewage in its higher reaches, becomes a few miles lower down so pure from a chemical point of view as to be certified by the most eminent anlysis

to be fitted for all domestic purposes, and is actually so used by millions of our population, is a fact which can not be gainsaid. Whether this process of purification be merely due to sedimentation and dilution, or to those factors, assisted by oxidation, is, however, a matter of trifling importance, since it is now fully recognized that the disease producing material is not the dead organic matter in solution, but the living organisms in suspension. The problem is not a chemical one, but a biological one.'

"The statement above is made by Dr. Thresh in his chapter on the self-purification of streams.

"In my opinion this statement in Dr. Thresh's treatise represents correctly the prevailing opinion to-day among students of this question. Similar statements appear in other English and in German treatises." (6329-0.)

Professor Sedgwick, the only witness relied on by complainant to sustain the contentions set forth under this head in their argument, when cross-examined, testified as follows:

"I believe that waters of running streams, sewage polluted, purify themselves by the flowing of the streams to a large extent under favorable circumstances. The rapidity of the flow would have something to do with the degree of purification. It is the time factor which comes in and that would be profoundly modified by the rapidity of the flow. Numerous reaches where the flow of the water was extremely sluggish and occasional dams checking the water would contribute to the purification of it. Such reaches and dams would contribute to the purification by other means than sedimentation, by detaining the germs present and thus favoring their dying out if they lay there long enough to die out. Mere detention apart from sedimentation would be a factor in this time factor I have spoken of.

"If near a given river there were numbers of small lakes or ponds which filled up during the overflow or high water of

the river and which contributed to the flowing stream of the river, when the water subsided, they would contribute to the purification of the stream in the proportion in which the supposed lakes and ponds afterwards contributed to the current of the stream. In times of flood, it would certainly contribute to the purification of that part of the water which was over lakes. If there was a flood in the Illinois River in which the waters overflowed the banks and spread out in the bottoms which continued for four weeks and in the bottoms there is no perceptible current of the river, those portions which stood upon the bottoms would certainly be purified somewhat. They would be purified so far as the sewage is concerned very considerably. I am familiar with the general physical characteristics of the Illinois River from studying maps and talking with men who have been up there. I understand that the bottom lands or the overflowed lands of the Illinois River are very considerable. The fact that the Illinois is a sluggish stream in its overflowed stages, that there are several dams and at times much so-called slack water, that in reaches of the river which are not affected by the back waters of the dams, there is in ordinary stages, in many places, and for long distances, a very slight fall, would aid in the purification of the waters of the Illinois River under ordinary conditions." (2261-2-3.)

The conditions referred to in Professor Sedgwick's testimony are those that are shown to apply to the Illinois River. Then towards the conclusion of the statement, he admits specifically that purification takes place in the Illinois River.

Professor Zeit testified as follows:

"Q. Professor, you stated yesterday, that the zone of bacterial purification of the waters of the Illinois River had been reached as disclosed in your examinations of that river, at Averyville, just above Peoria. Will you please state what is considered by you and by bacteriologists generally, as the zone of bacterial purification of a river?

"A. The zone of bacterial purification is that part of a sewage polluted river, where saprophytic organisms and pathogenic bacteria have disappeared and where the normal bacteriologic flora of the river, before it received such pollution, is again established. In other words, where practically the same bacteria are found or exist that are found in the same river before it receives such pollution. The zone of bacterial purification varies in the different localities and in the different cities that empty their sewage into rivers, in its distance between very short distances, as short as nine miles, and longer distances, to the extent usually of forty miles.

"Q. Can you give any examples of other rivers where the zone of purification has been ascertained by bacteriologists?

"A. Yes, I can. The river Seine in Paris has 70 kilometers below the City of Paris, after receiving all of the sewage of Paris, the same bacterial flora practically having the same number of micro-organisms, that the river Seine had before it entered the City of Paris. This is a distance of 43 miles.

"The River Oder at Breslau receives the sewage of the City of Breslau 32 kilometers below the city it has the same number of bacteria again that it had before it entered the City of Breslau.

"In the City of Zurich, Switzerland, we have the lake sending out a river, the Limmat. The lake water contains only few bacteria to the cubic centimeter and is considered very pure—200 about, 100 to 200. The river receives all the sewage and the effluent of Zurich, and has again, 33 kilometers below the city, practically the same bacteriological flora as it had before receiving the sewage.

"Q. How many miles would that be?

"A. I see I made a mistake with regard to the distance. The Limmat had its zone of purification nine miles, or 14 kilometers from the source of pollution. If you care to hear

the number of bacteria found at the different places, I have them here.

"Q. 33 kilometers is how much?

"A. 33 kilometers is the purification zone of the Isar, in Munich. 33 kilometers is about 20 miles.

"Q. How many feet are in a kilometer?

"A. 100 kilometers is about 62 miles, and it is on that scale that I am figuring out these distances.

"Q. Now proceed, professor, if you have any other instances?

"A. The Isar at Munich, in a distance of 20 miles, after receiving the sewage of the City of Munich, again—

"A. The Limmat in Zurich, the investigation was made by Schlatter—Zeitschrift fur Hygiene, page 56, volume 190, which is a journal on hygiene. The first I gave you, the River Seine, you will find in Rubner—Hygiene, Berlin.

"The Oder you will find—I have not the data of that here, but you will find them also given in Frankland.

"The Isar at Munich shows a zone of bacterial purification which is complete 33 kilometers below the City of Munich, or twenty miles. This is given in Prausnitz,—Hygiene.

"Mr. Jeffries: When were these data compiled?

"A. The Rubner in 1901; the Prausnitz is I think 1900 or 1901. I will bring them here so you can have them.

"Q. Judge Springer: They are in German, in the German language?

"A. Yes, sir. The Spree, in Berlin, also receives sewage which then allows the bacteria to raise up to 1,000,000 per cubic centimeter. Then it goes into the small lake of Havel and at the exit of that lake, or Sacrow the bacteriological flora is again the same as it was in the River Spree before it en-

tered the City of Berlin. This is given also in the Zeitscrift fur Hygiene, page 355, volume 3.

"Q. Do you know the width of that lake and its length?

"A. I do not. It is a small lake, but I do not know its length nor its exact diameter.

"Q. In Frankland's Micro-organisms, it is given as seven miles long. This lake is?

"A. I should judge that the whole distance traveled was about nine miles, but I am not positive about this distance. I think nine miles would be a fair allowance.

"Q. State whether the authors you have mentioned and to which you have referred are recognized authorities upon such subjects?

"A. Rubner is professor of hygiene in Berlin. His text-book on hygiene is considered the standard book, and Praus-nitz also is one of the standard text-books; and the others quoted in the various journals also are considered good men. These determinations have been mainly made under the supervision of the government laboratory. The first work for instance, in Berlin was done by Koch the discoverer of the tubercle bacillus. Some of these facts were already determined by Koch, before these later publications which went into the question much more thoroughly than had ever been done before."

"Q. Judge Springer: State whether the instances which you have cited are recognized by bacteriologists as a part of the accepted literature upon this subject.

"A. I think this is mainly a question for sanitarians to consider and is not so much a question of pure bacteriology. This is a question of the application of bacteriology to hygiene, and these authorities I have mentioned, would no doubt be recognized by any sanitarian as well as bacteriologists, as competent and reliable.

"Q. Returning then to your conclusions in reference to the zone of bacterial purification having been reached at Peoria, state whether the conditions which you took into consideration, and upon which you reach this conclusion are materially different from those existing elsewhere, where a similar conclusion has been reached as to other rivers?

"A. I think the zone of purification here ought to be even nearer to the City of Chicago, than what I have allowed. In fact, I think that the zone of purification is above Upper Peoria. I spoke of it simply there as being bacteriologically complete. I believe that the real zone of bacterial purification, is complete very soon after leaving the Drainage Canal." (4464, *et seq.*)

Professor. Sedgwick is laboring under a misapprehension when he states that "it was formerly believed by experts that running water purifies itself. That belief has been abandoned." He testified differently in this very case, and as a result of his testimony the following examination was had of Professor Jordan, which explains Professor Sedgwick's testimony on this subject:

"Q. Professor Sedgwick on page 369 of the transcript of his testimony, an uncorrected copy of which I have stated: 'The River Commissioners of Great Britain, in a report published by them in 1874, state there is no river in England long enough to purify itself from any sewage admitted to it, even at its source;' that stands as one of the axioms of sanitary science today, that those River Commissioners in 1874 I think it was made that statement that there is no river in the United Kingdom I think they said, long enough to purify itself of any sewage introduced into it, introduced at its source, and of course some of the rivers of the United Kingdom are very long.' And again, on page 4398, this question was asked him: 'Do you know how the distance from Cumberland to Washington by river compares with the length of

the River Thames in the United Kingdom' answered 'The Thames is 209 miles long and is, I believe, the longest river in the United Kingdom, and this epidemic seems to confirm in a very remarkable way that statement of the Rivers Pollution Commission of Great Britain to which I have referred in my previous testimony where they said that there was no river in the world that was long enough to purify itself of any sewage introduced into it, even at its source.' I will ask you if you are familiar with the report of the River Pollution Commission of Great Britain for 1874?

"A. Yes, sir, I have frequently consulted it in connection with my teaching and investigation work.

"Q. Will you state what the River Pollution Commission Report for 1874 did state about river purification?

"A. The statement is as follows:

"'It will be safe to infer, however, from the above results that there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation.'

"Q. What is the difference between the expression 'to effect the destruction of sewage by oxidation' and the expression 'to purify itself of any sewage introduced into it at its source?'

"A. At the time this report was published in 1874, the knowledge of sanitarians regarding the quality of a water was based on chemical data, this being before the rise of the science of bacteriology. Practically nothing was known at that time regarding the elements in sewage that imparted to it its dangerous character. The fact had, however, been determined empirically that a certain relation existed between the oxidation of sewage and the loss of its dangerous qualities. It was not known however precisely what this relation was or upon what it depended. At the present time our conception of the purification of a sewage-polluted stream is based rather upon what information we are able to obtain regarding the

disappearance and destruction of disease producing bacteria that may be introduced into it rather than upon oxidation processes. There is, therefore, a wide difference between stating that the purification of a stream is effected within a certain distance and that the destruction of sewage by oxidation is accomplished within a certain distance. It does not, by any means, follow that because complete destruction by oxidation of the organic matters contained in a sewage polluted water does not occur within a specified distance, that the real purification of the sewage, that is to say its freedom from dangerous bacteria may not be accomplished within that distance. It is certainly true that the process of nitrification or oxidation and the processes leading to the disappearance of dangerous or suspicious bacteria do not always run in a strictly parallel course either in sewage tanks or polluted rivers.

"Q. Does the report of the Rivers Pollution Commission of 1874 contain anywhere in it the statement that no river in the United Kingdom is long enough to purify itself of any sewage introduced into it at its source?

"A. I have examined this report with some care and have failed to discover in it any statement couched in the language you have just used." (6172, *et seq.*)

Professor Zeit is of the same opinion as Professor Jordan on this subject, for he says:

"Q. Well, has bacteriology got anything to do with the science of hygiene?

"A. Yes, in so far as hygiene has originally taught us that there was no river long enough that it could purify itself of any pollution it received, and as bacteriology has proven that that dogma is not correct and that there is in every river a purification zone.

"Q. I want to ask you the proposition, professor, if the doctrine has not grown into existence, right the reverse from

what you have stated; that the original belief was among scientists, that a river running a long distance would purify itself, and that modern science has turned back on the original proposition?

"A. English authorities on hygiene have taught twenty years ago that no river was long enough that it could purify itself of any pollution it received.

"Judge Springer: No river in Great Britain.

"A. (Continued) And as soon as bacteriology was employed in the examination of river waters, as to the possibility of determining the quality and effects of pollutions an entirely different condition was found than that which was generally accepted by the specialist on hygiene. It was found that there is a zone of bacterial purification in every river and that sewage bacteria turned into it really disappeared within a certain distance. I, as a bacterioligist, have of course accepted that view, and, based upon my own findings in the matter, have expressed it also as my opinion that there is a bacterial purification zone in every river." (4495-6.)

On pages 243 and 245 of argument Professor Sedgwick quotes the Pittsburg instance as having a bearing on this subject. This is the longest distance referred to by Professor Sedgwick and for that reason we will now consider the facts in that particular case.

As explained under the heading of "Epidemics" in the first part of this argument, there never was an epidemic of typhoid fever in Pittsburg, and it never was shown that typhoid bacilli came from Oil City to Pittsburg, but Professor Sedgwick did say in his report that "foul water introduced for example at Oil City or nearer points may and indeed must arrive at Pittsburg within a very few hours." And owing to that fact he advised that the water supply of Pittsburg be filtered. That is all there is to the supposed epidemic of Pittsburg being caused by typhoid bacteria from Oil City.

There is not a scintilla of evidence to show that the bacteria did come from Oil City—merely a guess of Professor Sedgwick's. It will be noted, however, that because this witness reported that he thought bacteria might come from Oil City to Pittsburg, he refers to the incident throughout his testimony as one of the classic cases in the literature of sanitation.

Let us then see what are the physical characteristics of the Allegheny River as compared to the Illinois and as relates to its facilities for self-purification. We do not have to go any farther than Professor Sedgwick himself for the information.

Turning to page 6168 of the record we find the following testimony of Professor Jordan:

"Q. How do the physical conditions of the Illinois River compare with the other rivers in the country for the purpose of purification?

"A. As compared with rivers of high velocity the conditions for purification in the Illinois River, as already set forth, are especially favorable. The sluggish current which permits a sufficient lapse of time for the death of pathogenic bacteria and which also facilitates and furthers sedimentation constitutes an element wholly favorable to self purification.

"As compared with the Mississippi River where the current is swifter and especially as compared with the Missouri River the opportunities for purification in the Illinois River are quite superior.

"Any factors that tend to increase the opportunities for sedimentation and that tend to delay the progress of pathogenic microbes down stream, further the process of purification. In these respects the conditions in the Illinois River are greatly superior to the conditions in the Mississippi and Missouri Rivers. As compared with some other streams in this country that have been studied with a view to the opportunities

for self purification the Illinois River is well adapted for self purification.

"I find in the report to the Filtration Commission of Pittsburg, Pennsylvania, published in January, 1899, in a report upon the Sources of Typhoid Fever in Pittsburg, by my friend Professor W. T. Sedgwick, who has testified in this case, the following statement: I will quote what he says about the Allegheny River under the heading 'The Allegheny River a rapid stream with little or no opportunity for self purification,' page 18.

" 'Any one who will take the trouble to follow the Allegheny River from Oil City to Pittsburg merely as a passenger on the Allegheny Valley Railway, particularly if he is familiar with the streams in the less mountainous parts of the country, cannot fail to be impressed immediately with the fact that we have in the Allegheny River a peculiar and characteristic stream? Owing no doubt to the character of the rock through which it has cut its way, it exhibits a very regular deep line from Oil City to Pittsburg. There is no mill dam of any consequent between these two cities and the river is therefore narrow as is not frequently the case with rivers in New England. (Note that this is the same person who testifies in this case that dams are of no benefit in the Illinois River), and elsewhere in which a series of mill ponds containing slowly moving water, and in which the elements of sluggishness and quiescence are except in period of freshets a chief characteristic, but rather, even at low water like a brawling brook, making its way rapidly over a stony bed in which are very few pools or other quiet places adapted to purification in which there is little or no evidence of effective sedimentation as is proved by the absence of mud banks, sand bars and the like—but exhibiting everywhere stones polished by the swiftly flowing stream and without effective lodging places for mud or bacteria. An estimate roughly made of the rate of flow shows

to the traveler a probable velocity in most places of at least a foot per second and often much more than this even at low water. With high water the velocity must obviously be much more rapid. Clearly the two fundamental elements looking towards self purification in rivers are here wanting, namely, time and quiescence. The velocity of the river and the character of its bed are such that foul water introduced for example at Oil City or nearer points may and indeed must arrive at Pittsburg within a very few hours. Fortunately however we do not have to rely on the rough observations of passing travelers but are in possession of authoritative calculations. According to results obtained from the United States engineer's office at Pittsburg the average velocity of the Allegheny River even during low water is from one to two miles per hour. During high water it is from 7 to 8 miles per hour and on the average of about three and one-half miles. This means that infectious materials poured in at Oil City or nearer points may arrive at Pittsburg within fifteen hours or even at low water must arrive within a few days.

"'It has just been shown that in the bed of the Allegheny River very little or no opportunity occurs for purification en route by the usual processes which are more or less effected in rivers.'

"I would say that I entirely agree with Professor Sedgwick that the Allegheny River as he describes it affords few opportunities for the process of self purification, and that I agree in his conclusions as to the rapid march of infectious material under such conditions. The conditions in the Illinois River, however, as hereinbefore set forth are very different from those prevailing in the Allegheny river. In the Illinois River as in other sluggish streams those elements that favor self purification in rivers, namely, time and quiescence, are present in force. There are few rivers in the United States with which I am familiar where the factors making for self puri-

fication are so potent as they are in the case of the Illinois River. Both the Mississippi and Missouri Rivers are less favorable in this respect." (6171-2.)

This report of Professor Sedgwick shows that he believes there is such a thing as the self purification of sewage polluted rivers and that time and quiescence are the two fundamental elements looking towards self purification. The record shows that these two conditions are more favorably found in the Illinois River than any river on record in the literature. Added to these two conditions we must not forget that pathogenic germs have a short life history in sewage polluted water —in fact the greater the pollution the shorter the life of typhoid bacillus. The Drainage Canal is practically a sewer for a distance of twenty-five miles and as we will show hereafter, typhoid bacteria and other pathogenic germs have lost their virulence before they leave the canal. In fact for twenty-five miles this sewage flows in the canal with all the purifying influences of septic action taking place—no additional sewage being introduced and no dilution taking place outside of that which occurs as it enters the canal. It can safely be said that there is no stream on record where the influences for self purification are as favorable as in the Drainage Canal and the Illinois River.

This record also shows that self purification takes place in many other streams in the United States. Let us see what witnesses for complainant testify in this regard.

As to the effect of the sewage of Alton on the Mississippi River, Dr. Ravold testifies as follows:

"From these figures it will be concluded from the biological results, that the sewage of the City of Alton has no effect on the sanitary condition of the Mississippi River at Hartford.

"Q. That is six miles below?

"A. Yes, sir." (779)

Professor Ravold is one of complainant's witnesses. He testifies that the sewage of Alton, a city of over 15,000 population, has no effect or has lost its bad sanitary character in a flow of six miles. In this connection we also call to the court's attention that this witness states this is due largely to dilution—although complainant argues throughout the case that the additional dilution of the sewage of Chicago with Lake Michigan water is an added menace to St. Louis. In fact the second part of this section of complainant's argument is devoted to stating that facilities for self purification in the Illinois are not now as good as prior to the opening of the canal because more water is flowing through the canal which decreases the opportunities for self purification. Yet Dr. Ravold states that this very dilution renders harmless the sewage of Alton in a journey of six miles in the Mississippi. Why should not what is true of the Mississippi River also be true of the Illinois?

This witness also says:

"Q. Now, if that is true, that the Mississippi River above Alton and below the mouth of the Illinois is more polluted than it is at Hartford 14 miles below, what deduction, as a chemist would you draw from that as to the effect of the sewage of the City of Alton on the waters of the Mississippi River, as to whether or not it increased or diminished perceptibly the pollution?

"A. The sewage of Alton apparently has no effect upon the condition of the river at Hartford." (1041.)

Professor Teichman, complainant's witness, believes the Mississippi River purifies itself for he testifies as follows:

"Q. Now, if the water of the Mississippi River at Grafton is potable, doesn't it convey to your mind as a chemist, that sewage discharged into that water at Minneapolis and St. Paul and all the cities nursing the banks of the Mississippi River,

has become purified to the degree of potability by the time it gets to Grafton, the point where you made your examination?

"A. Stating as I have done, that I am not familiar with the conditions, whatever pollution there might have taken place in that Mississippi River above the mouth of the Illinois river; whatever pollution has taken place, it has been rendered sufficiently harmless by the time that water reaches the mouth of the Illinois as to render that water potable during certain times of the year, as I have stated." (1474.)

If such a condition takes place in the Mississippi River, greater purification takes place in the Illinois River for the opportunities for self purification are better in the Illinois than in the Mississippi.

However, it is admitted that purification takes place in the Illinois River by complainant's own witnesses.

Professor Teichmann also states that the sewage of Peoria purifies itself after a run of from 25 to 50 miles. He says:

"In other words, if we take the sewage of the City of Peoria and run it into water at such a ratio of dilution, the sewage would, in my opinion, after a run of from 25 to 50 miles, be sufficiently purified with so much water added to the sewage, so as to remove the effect—the polluting effect of the Peoria sewage on that river. * * * That is, would certainly have finished the purifying process after having run the distance that I have mentioned." (1214-5.)

Professor Teichman says:

"The very high results of free ammonia found in the water at Joliet are reduced somewhat by the time the water reaches Peoria. In other words, the initial process of purification has been materially facilitated during the transit of the water in the Illinois River from Joliet to La Salle and Peoria." (1263.)

Professor Teichman also says:

"From the analyses of the Desplaines I considered that

water potable water. That opinion was arrived at from the analyses of the water in that river just above its junction with the Drainage Canal. I mean that it was good drinking water for those two months.

"Q. What is the volume of the Desplaines River?

"A. You mean--

"Q. In water?

"A. Just before it reaches the Drainage Canal?

"Q. At the point where you took your samples?

"A. Well, the volume there varies very much according to the statement of the chief engineer, Mr. Randolph, of the Drainage Canal.

"Q. About the time that these samples were taken, doctor, is what I am interested in?

"A. Well, that I couldn't tell you at this moment; I would have to look up the data.

"Q. Was it high water or low water in the river at that time, do you know?

"A. I cannot recollect at this moment; I knew it at the time.

"Q. And you say that that water was potable?

"A. Yes, sir.

"Q. You mean by that, good drinking water?

"A. Yes, sir.

"Q. Do you know what towns empty their sewage into the Desplaines River?

"A. I do not know at this moment.

"Q. Do you know that the sewage of Riverside, of about 5,000 inhabitants, empty their sewage into the Desplaines River above that point, and the village of La Grange?

"A. I know that some towns drain their sewers into those rivers—into that river.

"Q. Do you know that the waters of the Desplaines River have been condemned by the Board of Health of the City of Chicago as being contaminated, and that ice men are prohibited from selling the ice from that river?

"A. No, sir; I don't know that fact.

"Q. If those facts should appear to you, that the village of Riverside, located within ten miles, and La Grange, and Maywood, and other suburban towns were draining their sewage into that stream, would you still call that a potable water?

"A. I drew my conclusions from the analytical data that we received from the analyses of those samples from the Desplaines River in October and November, 1901, and I feel justified in stating that from those analytical results I must consider the water of the Desplaines River for those two months at least, of our examination, as a potable water, just at the point before the Drainage Canal discharges its waters into the Desplaines.

"Mr. Jeffries: You haven't answered the question, doctor.

"The Witness: Would you please repeat the question and I will answer the question.

"Mr. Todd: The reporter will read you my question.

"(Question read.)

"A. I could only base an opinion on the analyses of the samples taken from that river.

"Q. Then if the sewage of these different places that I have indicated, does empty into the Desplaines River, and did empty at the time that you made your examination, purification of that sewage had been completed at the point that you made the examination. Is that correct?

"A. Yes, sir; if the facts are such; provided, however, that the volume of water was sufficient, and the Desplaines River at times can discharge as much as 600,000 cubic feet of water per minute.

"Q. Well, assuming the volume of water that was there at the time that you took the samples out of the Desplaines River, can be ascertained, and I assume that it can—you could give me the data on that couldn't you?

"A. Yes, sir.

"Q. And assuming also that the sewage from these points above there was emptied into that river, before that sewage got to the point that you took your samples, it had been purified, and the water had been rendered potable according to your analyses, is that correct?

"A. Yes, my analyses established the fact that during those two months the water taken from the Desplaines River was potable before it reached the Drainage Canal.

"Q. The condition of purification in the Desplaines is not different from the conditions obtaining in the Illinois, is it?

"A. Well, it depends very much upon local conditions. They may change the conclusions very much. No conclusions can be based absolutely on certain facts without taking into consideration the general conditions; the volume of water and the character of the sewage, and the population of the towns draining their sewage into the river.

"Q. Well, I mean the principles of purification will apply to the Desplaines River the same as to any other river, would they not?

"A. Well, if the conditions were alike, of course.

"Q. Well, that is the principle, depending upon conditions?

"A. Yes, but the general—a general assumption nowadays

is that local conditions have to be taken into consideration in determining a question of purification.

"Q. What is your opinion, doctor, as to the effect of running water on sewage? Does it purify itself or not?

"A. That depends very much upon the conditions prevailing in those running waters, and the volume of water, the character of the sewage; the question would come into consideration whether or not pathogenic germs are contained in that sewage, and various other questions that all would have to be considered before a general opinion could be formed in each case." (1457-8-9.)

This testimony of complainant's witness shows that the "general assumptions," to use his own words, of other witnesses for complainant, who have no knowledge of the actual conditions of the Illinois River except such as they may have gained from a study of a map (never having made a personal examination of the river), should have no weight with this court.

Professor Teichmann, witness for complainant, admits that the Missouri River purifies itself of the pollution discharged into it by the time that river reaches Bellefontaine, which is near its mouth. (1495.) It will be remembered that the Missouri River is a much swifter stream than the Illinois and has no dams in it. He says:

"The character of the sewage entering the Missouri River at Kansas City is that of the city, a sewage very high in percentage of refuse matter from slaughter-houses and rendering establishments, and it contains 60 per cent. of the sewage of Kansas City as discharged into the river. This sewage of course includes the fecal matter—it includes all the dirt in the streets as swept into the sewers from rainfall or from street sprinkling. There are a very large number of slaughter-houses there.

"Q. It is a vast amount of sewage, isn't it, that enters the

river at Kansas City from slaughter-houses and other manufactories?

"A. There is considerable sewage entering from that source; yes, sir.

"Q. Does that sewage from Kansas City purify itself in the Missouri in going 400 miles?

"A. The chemical analyses of samples of water taken at Fort Bellefontaine show that whatever sewage pollution has taken place from the sewage of Kansas City that sewage pollution has to such an extent disappeared that when the water reaches Fort Bellefontaine, after a run of 403 miles, that water is potable at Fort Bellefontaine." (1509.)

He also says:

"Q. Then how can you state that the waters of the Missouri River all the time are potable, in view of the fact that when the current of the river is four miles an hour, and it is only 403 miles from Kansas City to St. Louis, which at that rate would be four days for the sewage to get from Kansas City to St. Louis, that the water is potable?

"A. I can only form the conclusion that the water is potable from the chemical analyses performed upon the water taken from the Missouri River at Fort Bellefontaine, and the water was potable." (1510.)

It will be remembered in this connection that the shortest possible time in which water can reach St. Louis from the south branch of the Chicago River is ten and one-half days, as ascertained by complainants, and to this is to be added the one and a half days or two days that the water remains in the reservoir at St. Louis and the time consumed for the sewage to go through the Chicago sewers and the Chicago River—the ten and one-half days being the figures given by complainant— defendants' experiment showing the actual time to be eighteen days.

But what Professor Teichmann says he did with the Mis-

souri River is exactly what defendants have done with the Illinois—they have made analyses of the Illinois River at Grafton showing that the water compares favorably with the Missouri and Mississippi and is better, if anything, than its tributaries, as will be shown hereafter. Teichmann says this is enough to show that the water of the Missouri River is potable regardless of the amount of sewage discharged into the river in its upper stretches. Why should not the same facts apply to the Illinois River?

Professor Teichmann also says:

"Q. Are there any exceptions to that rule, doctor, that the Missouri River purifies itself in going 400 miles?

"A. Well, that I am not prepared to say because I found that during the winter months, the cooler weather retarding the process of oxidation and mineralization of the organic matter in the Missouri River, I say that the chemical results of the analyses of samples showing at Fort Bellefontaine the same pollution of the water, I am not prepared to answer that question." (1565.)

Here we have Professor Teichmann on record as admitting that he is not prepared to state that there are any exceptions to the rule that the Missouri River purifies itself in going 400 miles.

Professor Sedgwick made a report of the Lowell, Lawrence and Newberryport epidemics. (866.)

Dr. Ravold was asked concerning this report and the action taken by the Massachusetts legislature:

"Q. I will ask you, Dr Ravold, if it is not a fact as a result of that report, that the legislature of Massachusetts passed a law providing that there should be no sewage discharged into the streams in that state less than twenty miles above the intake of water supplies?

"A. I think a law of that kind did come into force, following that." (867.)

This shows that the legislature of Massachusetts after reading Professor Sedgwick's report, must have come to the conclusion that a twenty miles flow was sufficient for the self-purification of streams.

Professor Whipple, one of complainant's witnesses, testified as follows on cross-examination:

"Q. Have you ever examined the investigations made in reference to the waters of the Spree, which supplies the City of Berlin with water?

"A. I believe I have seen examinations of some kind from the waters of that river; I don't recall just at present though, what they were.

"Q. Well, you understood that until recently the water supply of the City of Berlin passed into the city from the river Spree, and I find in the book to which I have called your attention a statement as to the conditions of the water before it entered the city and at a few miles below the city, after it had passed through the city, and obtained its sewage. I find it stated here that at Saerow, which is the end of a small lake a few miles below the city, the water had resumed its normal condition before it entered the city. Have you had occasion to examine the conditions under which that purification took place?

"A. I think I remember reading about the case. I am not able to recall at the present moment just the conditions, but I think you mean that the water above the city contained a certain number of bacteria, and that immediately below the city, below the entrance of the sewers, the number of bacteria was much higher, and then again further down the stream, below that lake, I think which you mentioned, or extension of the river—

"Q. Havre Lake?

"A. The numbers again were as low as they were above the city. I think I remember reading that fact.

"Q. This lake into which the water of the Spree entered is called Havre Lake, and is several miles in length, as stated in the books, and at the end of that lake, which was only a few miles—a very few, less than ten, from the city, the water had resumed its normal purity. This was attributable in that case to the sedimentation of the bacteria in the lake. I will now ask you, after having made this suggestion, whether you have considered the question of sedimentation in the Peoria Lake, and in the other lakes in the Illinois River, and especially in the dams across that river at various points to which your attention has been called in determining whether it were possible for typhoid bacteria to be carried from the Chicago River by way of the Drainage Canal into the St. Louis intake?

"A. Yes, I considered the question of sedimentation in those expansions of the river to which you refer, the Illinois River, and it is my opinion that under certain conditions sedimentation of bacteria might certainly occur in those places.

* * * * *

"Q. Would the presence of 300,000 cubic feet of water of Lake Michigan, in diluting the sewage of Chicago, and the waters of the Illinois River, have anything to do with bacterial conditions that might appear in the Illinois River at Grafton?

"A. The more the sewage of the Chicago River was diluted—I would say, the sewage of Chicago, and the Chicago River was diluted with the water from Lake Michigan, the smaller would be the number of bacteria in the water after this dilution.

"Q. And the less likely would that bacteria be to produce injurious results?

"A. Well, I could not say that dilution is destructive of bacteria.

"Q. The probability of removing its presence?

"A. The greater the dilution the less the probability would be of finding the typhoid fever bacillus, for example in a glass of water, but dilution,—mere dilution of the bacteria so far as the dilution alone is concerned, is not destructive of bacteria.

"Q. But the amount of dilution increases the chances of pollution at a given point, does it not?

"A. You mean decreases? Would decrease the amount of pollution?

"A. The greater the amount of dilution of a polluted water, the less danger there would be from drinking this water, so far as dilution alone is concerned.

"Q. Yes, that is what I meant. I want to call your attention to an experiment in reference to the waters of the river Limmat which flows out of Lake Zurich. It is stated in the work to which I called your attention, that the average number of micro organisms in the water of Lake Zurich was from 100 to 200 per cubic centimeter. The River Limmat flows out of the lake. A sample collected below Zurich, after it had passed through the city and before it receives its drainage, showed that already in its flow through Zurich it has become more or less contaminated. The increase in the number of bacteria is however, very much more marked below the point of the sewage outfall, and after the rain or snow, has fallen, the numbers show a decided increase, and this is specially exhibited so this author states, in the experiments of January 28th, and 30th and February 15th and 16th, and other experiments being particularly instructive in this respect, as many as 24,000 micro-organisms being found at Extringingen in one cubic centimeter of water; at Dietikon, after a flow of ten kilometers, which I understand to be six miles, the bacterial condition of the water approaches very often to that of the river before the introduction of the sewage.

"In view of that instance noted in this work, and assuming that the conditions stated there are true, is it not very highly probable that the waters of the Illinois River at the Narrows, above Peoria, a distance of over 100 miles from Chicago, would have obtained a bacteriological condition which those waters had before the reception of the Chicago sewage?

"A. It is my opinion that without knowing more about the conditions which actually existed where those experiments were made, the results obtained would not be of any material value in judging as to what would be the bacteriological conditions at Peoria, but the experiments made, seem to be in line with what is generally known in regard to the decrease in the total number of bacteria in streams below points where they become polluted, and it is quite conceivable that the conditions in the Illinois River between the Chicago Drainage Canal and Peoria are such that the total numbers of bacteria in the Illinois River at that point might be as low, or even lower than the numbers of bacteria in the waters of Lake Michigan before it received the sewage of Chicago, but I would add to that that when we speak of the bacteriological condition we must consider not only the number present, but also the character of those bacteria.

"Q. If the number of ordinary water bacteria decreased during this interval of time, and distance, would not the pathogenic germs decrease in like proportion?

"A. The probability is that pathogenic germs would decrease, but whether or not they would decrease exactly in proportion to the water bacteria is a thing which I cannot state.

* * * * *

"I don't know that I ever made any direct comparative experiments, but it is my general impression from experiments which have been made, that at most temperatures water

bacteria would live longer in water than the typhoid bacilli, but of course that all depends upon the character of the water bacteria and the character of the water, the temperature and other considerations. I have made a good many experiments covering both phases of the subject, but perhaps never any particular one set to bring out just that one point.

* * * * *

"A. If we neglect all other conditions, such as sedimentation, etc., etc., and consider only the fact that typhoid bacilli do not multiply in water, while water bacteria do multiply under the conditions assumed, why then it is probable that the typhoid bacilli would not linger in water as long as the bacilli which multiplied there, but as a natural practice, it would not do to neglect all such other considerations in studying a problem of that character.

"Q. I am only asking your opinion upon the conditions suggested; of course there might be other conditions.

"A. I have given my opinion under those conditions.

"Q. Are you familiar with a stream in Scotland known as the River Dee?

"A. Yes, sir, I have heard of it; I never saw it.

"Q. The stream upon which the City of Aberdeen is situated. The book to which I called your attention, by Percy and G. C. Frankland, on pages 100, 101 and 102, referred to experiments made by one of the authors by bacteriological examinations of the waters of that river in July, 1892. I will not read the results of this as stated here, but call your attention to the fact which is here stated, among other things, that the water in the river on reaching Invercannie, which is the mouth of the river or near the mouth, exhibited just about the same number of micro-organisms as it did at the first point mentioned, and that the total number of miles of the river's flow, which were examined bacteriologically, was a

little upwards of forty miles; that the distance was upwards of forty miles, and during this time, this work states that there were as many as four different sources of pollution entering the river, and that after each one the river reached its normal condition, and came out at the end comparatively, bacterially pure, as stated by this writer, the river thus affords a most perfect example of the repeated pollution and repeated restoration of a stream to a state of comparative bacterial purity.

"In view of these facts which have been ascertained by an acknowledged authority on the subject of bacteriology, is it not highly probable that the waters of the Illinois River in passing from Joliet to the Narrows above Peoria, a distance of over 100 miles, were rendered bacterially or comparatively bacterially pure by reason of the sedimentation, oxidation and other causes tending to the purification of running water?

"A. It is my opinion that the conditions which exist in the River Dee, have not been described with sufficient completeness as to the amount of dilution received, in the course of the streams, the amount of sedimentation, etc., which might take place, to enable a fair comparison to be made between the River Dee and the Illinois River.

"Q. Doesn't the mere fact that this River Dee received pollution at four different places in the stream and that it purified itself four times during forty miles, tend to show that other streams will purify themselves in traveling a given distance?

"A. It will tend to show that other streams would act in the same manner where the conditions were the same, and I may add that the result which you have described as having been obtained in the River Dee agree generally with many results which I have observed in other streams. It is a general fact that if a stream is polluted at a certain point and the water of that stream contained a certain number of the

bacteria below that point of pollution, that a decrease in the number of bacteria is often noticed down stream due to a variety of causes.

"Q. If typhoid fever should exist at the same time in cities on the banks of a given stream of water, which of the cities—the up-stream or the down-stream cities, would be in the most unfavorable condition so far as being affected by the presence of dejecta from typhoid fever patients in those streams?

"A. That would depend upon the amount of the typhoid fever dejecta discharged into the stream at various points and it would be influenced by question of dilution and sedimentation and a number of such factors. I fear, however, I don't fully understand your question.

"Q. Well you have comprehended it; that is what I wanted to know. If there was an epidemic of typhoid fever in the City of St. Louis, for instance, and the dejecta of typhoid patients were cast into the Mississippi River, what effect would you conclude would be produced upon the persons living in the cities below St. Louis, which derive their water supply from the Mississippi River?

"A. Well, that would depend upon the extent of the epidemic in St. Louis and upon the amount of dilution which the dejecta might receive in the river and upon the location of the cities down stream which might receive that water, and upon the time required for the water to pass from St. Louis to the other city and upon the rate of dying out of the typhoid bacilli; upon the sedimentation and upon factors of that sort.

"Q. Assuming that the cities on the Missouri and Mississippi Rivers in the year 1890, were visited by a typhoid epidemic, of more or less extent, and the sewage of the repective cities was emptied into the Mississippi and Missouri Riv-

ers, would the pollution and the danger from the presence of typhoid bacilli increase as you passed down the streams?

"A. Speaking very generally, the danger of contracting typhoid fever by drinking the water of those streams would decrease down the stream.

"Q. Would decrease or increase?

"A. Wolud decrease down the stream, but in this we should have to consider the relative amount of dilution which took place down the stream and such factors as the dying out of the bacilli and sedimentation and other factors, of which I have already spoken in previous answers.

"Q. Then there might be conditions of sedimentation which would cause a decrease of the danger, or in the number of pathogenic germs?

"A. I can conceive that if in passing down the stream the typhoid fever bacilli settled to the bottom of the stream, and if no other influences ever came about to lift them again into the water and carry them down stream, that so far as those bacilli that would settle out, were concerned, the danger down stream would be decreased.

"Q. Would be decreased?

A. Yes, sir, if the bacilli settled out of the water, at a certain place, and remained there from that time on, there would be no danger from that particular bacillus down stream.

"Q. Then the danger of contamination of the lower river would be lessened in proportion as the pathogenic germs were eliminated by the sedimentation and other causes to which you have referred?

"A. The danger from drinking the water in the stream further down the river is certainly lessened in proportions as typhoid fever germs are actually eliminated from the water.

"Q. In the United States census for 1890, there is contained some data for cities of 50,000 inhabitants and upwards, for the year 1890, in reference to the deaths from typhoid fever per 10,000 living persons in certain cities. At Denver, Colorado, for instance, population 106,000 in round numbers, there were 21.7 deaths per 10,000 living persons;

"In St. Paul there were 6.9 deaths per 10,000, with a population of 133,000;

"In Minneapolis, with a population of 164,000, there were 5.7 deaths per 10,000 persons;

"In Memphis, with a population of 64,000, there were 5.1 deaths per 10,000 persons;

"In Omaha, with a population of 140,000, there were 4.5 deaths per 10,000.

"Mr. Jeffries: What year is that for?

"The Witness: 1890.

"Judge Springer: 1890; United States census for 1890.

"Q. (Continuing) In Kansas City, with a population of 132,000, there were 4 deaths per 10,000 persons;

"In St. Louis, with a population of 451,000, there were 3.2 deaths in 10,000;

"In New Orleans, with a population of 242,000, there were 1.9 deaths per 10,000.

"Of these cities, Denver receeived its water supply from the North Platte River, a river which empties into the Missouri near Omaha; St. Paul receives its water supply from lakes near that city, and Minneapolis from the Mississippi River; Memphis receives its water supply from artesian wells; Kansas City from the Missouri River and St. Louis from the Mississippi River, and New Orleans from the Mississippi River, and Omaha from the Missouri River. All of these cities, I believe, have sewerage systems emptying into the Missouri and Mississippi Rivers, except Denver, which receives its supply from the North Platte River, which emp-

ties into the Missouri. How do you account for the fact that the death rate of New Orleans, which was 1.9 per 10,000 persons, was less than it was in any of the up-stream cities to which I have referred?

"A. I cannot account for it without considering a series of conditions, many of which are quite unknown to me. I can conceive it possible that in so far as the typhoid fever existed in these various cities, and in so far as that sewage from typhoid fever patients drained into these streams, and in so far as typhoid fever bacilli may have reached the water supplies of the cities further down on those streams, that those cases of typhoid fever in the upper cities may have had some influence upon the lower, but the amount of the influence, I could not state. I do not know all the conditions which exist with regard to the decrease in the typhoid fever bacilli at the different places, or the relative effects of the sewages of the different cities on the streams below. In short, the problem is too big a one to be solved without knowing many more conditions than anything that I have at hand at this moment aside from these figures.

"Q. Assuming the facts to be as stated in this data, taken from the census of 1890, is it not apparent that the sewage from typhoid patients which carried typhoid bacilli into the Missouri and Mississippi Rivers, was so diluted by the waters of the two rivers, and the bacteria therein so far destroyed by sedimentation and oxidation, and by being lost on the banks and bottoms of the rivers, that they did not reach the lower Mississippi in quantities to increase the ordinary conditions which would otherwise have existed.

"A. I have no doubt that starting with Denver and the Missouri River and St. Paul on the Mississippi River, and continuing down the two streams, both before and after their junction, that in so far as the bacilli—typhoid fever bacilli in the sewage of those cities were concerned, there was an

increasing dilution; there may have been sedimentation; there was no doubt a dying out of the typhoid fever bacilli. On the other hand some of the bacilli which settled may have been again carried into suspension and borne a distance, possibly to be again settled; possibly to be again carried on, and I should judge from these figures, that the water which was being used by the people of New Orleans, for example, was less dangerous from the standpoint of typhoid fever, than the water which was being used by the City of Memphis, for example, assuming that there were no local conditions or no other conditions to account for the difference in the typhoid fever rate. In short, the death rate from the typhoid fever in the two cities for a certain perior offers a fair index for the comparison of the danger of the two water supplies for the period, irrespective of other causes which might account for some of the cases, aside from the water." (2139-44.)

One of the mose remarkable instances of the self-purification of rivers is that of the Mississippi River. This river, after receiving the sewage from and draining the entire Mississippi Valley, by the time it arrives at its mouth at New Orleans has recovered itself and reached a stage of purification which makes it a water that is characteristic of the non-polluted water of that region.

Robert Spurr Weston, a chemist made an extensive examination of the waters of New Orleans and testified in this case as follows:

"In 1900 I was in direct charge of the water purification station at New Orleans and conducted an investigation lasting eight months as to the feasibility of purifying the Mississippi water. I have been in private practice, exclusive of this last period, for six years.

"The distances of leading cities on Mississippi River or its tributaries above New Orleans is as follows:

Baton Rouge,	132 miles.
Natchez,	265 miles.
Cairo,	965 miles.
Cincinnati,	1,415 miles.
St. Louis,	1,159 miles.
St. Paul,	1,823 miles.
Vicksburg,	366 miles.
Memphis,	735 miles.
Louisville,	1,305 miles.
Pittsburg,	1,875 miles.
Mouth of the Missouri River,	1,165 miles.

"The United States Census for 1900 showed the population in cities of 4,000 or more in the Mississippi Valley to be about 9,000,000, including Chicago. I have prepared an estimate of the amount of sewage sewering into the different rivers, which make up the watershed of the Mississippi River.

"I have assumed that cities which have a population of 25,000 and over will discharge 175 gallons per capita of sewage per diem. I have assumed that the remainder of the urban population would produce 100 gallons per day per capita of sewage.

"I estimated the amount of sewage from large cities, that is, cities above 25,000 population, to be 1,174,250,000 gallons per day. I estimated the amount of sewage from the remainder of the urban population, that is, the remainder of the population of cities from 4,000 to 25,000 to be 342,000,000 gallons per day, making a total of 1,516,250,000 gallons a day. This is equivalent to a flow of 2,310 cubic feet a second at New Orleans.

"In 1900 and 1901 an experiment was conducted for eight months and data was collected for somewhat longer time to determine the best method of purifying the Mississippi River water at New Orleans. The data consisted of analyses, engineering data and reports.

"I had charge of the chemical and bacteriological analyses conducted at New Orleans at this time.

"These surveys of the waters of the Mississippi took place from the last of November until the following September and analyses were made, as a rule, daily at one point, located at the upper confines of the City of New Orleans and where the experiment station took its water for experimental purposes.

"The analyses show that apart from the nitrogen as nitrates and nitrites, that the water is characteristic of the non-polluted water of this region. An abundance of oxygen is always present in the water, showing that the organic matter has been decomposed to about the limits, the number of bacteria are very low and are chiefly associated with the suspended matter. When the suspended matter is removed the water is of excellent quality.

"Colon determinations were made during the flood seasons, that is from December, 1900 to April, 1901.

"Bacillus coli was only found on three occasions during the five months of the tests. It was found during the first week of December, 1900. It was not found subsequent to that date. When the bacilli were found in 1900 they were found in a small volume of water, namely 1 cc. They were not found subsequent to the first week in December. The presence of these organisms in the water at this time and not at any other times is explained by the fact that on the bank of the river immediately above the intake of the water purification station a number of house boat men and squatters were quartered. During the low water season these people had thrown their feces on the bank of the river, and during the rise it is easy to account for the presence of bacillus coli in the intake of the water purification station at that time, especially so because the intake was located near the bank of the stream and was suspended from a house boat, but in comparatively shallow water.

"100 coli determinations were made during this investigation and the coli was found present only three times. I arrived at the conclusion from the results of these coli determinations that no *unpurified sewage was present in the Mississippi River at New Orleans.* Assuming the velocity of the stream at four miles an hour, which is neither the maximum nor the minimum, the sewage from Baton Rouge would reach New Orleans in 33 hours after it was discharged into the Mississippi River. The velocity of the Mississippi at New Orleans may be taken at four miles per hour. A fair average of velocity for that river from Cairo to New Orleans is about four miles per hour, certainly no more.

"From my knowledge of the amount of pollution entering the Mississippi River through its tributaries and the population living upon the watershed, and from the chemical and bacterial and coli determinations, the results of which I have offered in evidence in my testimony. In my opinion there is not the slightest evidence that any unpurified sewage exists in the water at New Orleans apart from that small amount which may occasionally have been washed from the banks of the stream outside of the levies or in the immediate vicinity of the water purification station intake during the time when the tests mentioned were made." (6869, *et seq.*)

As to the second part of counsel's argument on this subject beginning on page 246 of complainant's argument under the heading "Facilities for self purification in the Illinois River were better under the conditions existing prior to opening of Canal than under conditions which have existed since the opening." This subject will be considered hereafter in this argument under the heading of "Purification of Illinois River."

We desire, however, to call the Court's attention at this time to the inaccuracies contained in the statements made by counsel for complainant under this head. At the end of the

first paragraph on page 247 of argument counsel quote "Sedgwick's testimony Vol. 3, page 2193." A reference to this volume and page discloses the fact that Prof. Sedgwick read from his book a statement to the effect that the quiescent state is conducive to the self purification of water. The other statements contained in counsel's argument on page 246 and 247 are the words of counsel and not of any witness in this case.

The Court will also find that not one of the references cited at the bottom of page 247 support the text. The references to Prof. Sedgwick's testimony on pages 2197, 2219-20, etc., do not relate to this subject at all. Whipple's testimony on pages 2085-6-7-8, is his cross-examination and is to the effect that the lakes and dams along the course of the Illinois River aid in its purification.

The references to Prof. Keiser's testimony have no reference and do not support the text to which they are attached.

To avoid repetition the conditions as to opportunities for self purification before and after the opening of the Canal will be discussed hereafter where it will be shown that although the current is faster since the opening of the Canal the relative amount of dilution as compared to the increased pollution is such that the water is now at all times purer than it was before and has reached a condition favorably comparing with its tributaries before it reaches the City of Peoria.

26

"THE DANGER TO THE PEOPLE OF ST. LOUIS AND MISSOURI CAUSED BY THE OPENING OF THE CHICAGO DRAINAGE CANAL IS ACTUAL, CONSTANT AND CONTINUOUS."

The subject-matter of the above portion of complainant's argument consists of the quotation of four pages of Mr. Williams and Prof. Sedgwick's testimony. No answer is required under this particular heading for as we contend there

is no danger whatever to the people of St. Louis and Missouri caused by the opening of the Canal, such supposed danger cannot be "actual, constant and continuous."

We submit that every question raised by complainant's under this heading is answered elsewhere in this argument.

27

THE SEWAGE OF CHICAGO HAVING NO EFFECT UPON THE WATERS OF THE MISSISSIPPI AT THE CHAIN OF ROCKS, THE EFFECT OF THE OPENING OF THE CANAL IS NOT SUCH AS TO PRODUCE AN INCREASE IN THE COST OF THE CONSTRUCTION AND OPERATION OF A SUITABLE FILTRATION PLANT TO PROTECT THE PEOPLE OF THE CITY OF ST. LOUIS AGAINST INFECTIOUS MATTER COMING FROM THE MISSOURI AND MISSISSIPPI RIVERS.

It will be noted by the Court that under this head beginning on page 252 of complainants' argument, the testimony of only four witnesses for complainant is quoted, viz.: Fuller, Smith, Alvord and Sedgwick.

On cross-examination, Prof. Sedgwick testified as follows:

"Q. Well, then, so far as the purification of the water of St. Louis is concerned at present, and rendering it fit for domestic use here for drinking purposes, the expense of doing that would be the same whether the sewage of the Sanitary District was in it or not, wouldn't it?

"A. The probable cost of doing it at present, owing to the conditions of the various rivers and at Chicago would, I should suppose not be materially affected by the addition of the sewage of Chicago to the Mississippi River as those rivers are and as that sewage is to-day." (2258.)

Allen Hazen, who is also a witness for complainant, testified as follows:

"Q. Would the cost (of a filter plant at St. Louis) be re-

duced somewhat if you could eliminate the water that comes into the Desplaines River from the Drainage Canal?

"A. Not materially." (2851.)

Mr. Hazen also states that in the construction of filters there may be an additional cost for a filter for the filtering of bacteria, but "in the case of St. Louis there would not be materially." (2844.)

Mr. Hazen, it will be remembered by the Court, was appointed by St. Louis as a commissioner in connection with Mr. Williams and Mr. Wisner to ascertain how best to supply the City of St. Louis with wholesome water. The commission was divided in their report, Messrs. Williams and Wisner reporting for a gravity supply from the Merrimac River. Mr. Hazen, however, made a minority report recommending the continuance of the Mississippi water with filtration. This witness further testifies that the construction of filtration plants and the designing thereof has been his main business. He states that is the department of his work upon which he is able to speak advisedly. (2803-4.)

Mr. Fuller, whose testimony is quoted by counsel for complainant under this heading, concurred with Mr. Hazen in a report to the City of St. Louis, dated 1902. This report was made two years after the opening of the Canal. On page 77 of this report Mr. Hazen stated:

"I believe that the raw water, although polluted far beyond the point where it should be used in its raw state is very much less polluted than many or most of the river waters used by American cities. Purification will remove a very large percentage of the bacteria and the elements of danger in the raw water. So far as there is danger to health in the present water it will be reduced by filtration to an almost inappreciable amount."

Mr. George W. Fuller, in commenting upon Mr. Hazen's

statements in this report says, on page 81 of the same report:

"With regard to this method of purification for the St. Louis water supply, it is my judgment that it will yield a water of satisfactory appearance and hygienic quality with proper construction and operation of the works and that it is the best and most applicable method for the conditions existing at and near the chain of rocks." (6256.)

This shows that Mr. Hazen had been officially appointed to make the investigation, and had every opportunity to determine whether the sewage from the Drainage Canal would add to the cost of filtering the St. Louis water supply. Mr. Fuller agrees with him that the water should be filtered and we submit that had Mr. Fuller made the same investigation as to the cost of the plant as Mr. Hazen did he would have come to the same conclusion. That is to say, that the water going through the Drainage Canal would not cause additional expense in filtering the St. Louis water supply. It will also be noted that these two witnesses for complainant in the year 1902, two years after the opening of the Canal, are on record in an official report as stating that the water supply of St. Louis "is very much less polluted than many or most of the river waters used by American cities."

The testimony of Dr. Herbert E. Smith, quoted by counsel for complainant in their argument should have no weight with the Court for the reason that Dr. Smith was not qualified to testify on this subject.

On page 7744 of the record on cross-examination he testifies that he has never recommended the use of river water without filtering; that he has never installed a filtration plant nor operated one; that he has never accepted bids for the installation of a filtration plant or passed upon the specifications of the bids, nor has he ever employed men to operate a filtration plant and passed upon the responsibleness of

their compensation. That he has never had any experience or paid any especial attention to the engineering side of such questions. He also states that he has had no experience with filtration plants in the Mississippi Valley. In fact he admits that he knows nothing about the subject. (7744.)

Cross-examination of Mr. Alvord the only other witness quoted by complainants in their brief shows that the only filtration plant he ever constructed was one used in one of the suburbs of Chicago costing about $7,000. He also states that he has designed a set of plans for Ottumwa, Ia., for a private company. He adds, however, that the chances are against those plans being accepted. He also states on page 7816 of the record as follows:

"Q. Would you put men in charge of a filter plant with less capability and experience if the sewage of Chicago was eliminated than you would if it were present?

"A. Not to any very marked degree. I should think I would be a little more cautious and would recommend a little greater expense, but I do not think that the difference in the cost of filtration would be very much affected by that particular item." (7816.)

Mr. Hazen, a witness for complainant, on cross-examination, testified as follows:

"Q. Well, then, would it cost any more to establish filtration plants, suppose that you eliminate the Illinois River and put in the Missouri and Mississippi River?

"A. It would make no substantial difference." (7869.)

Prof. Sedgwick's testimony should also be disregarded by the Court for the reason that he admits on cross-examination that he is not qualified to testify on this subject. He said, in answer to the following question:

"Q. Suppose that a filter was constructed which would at all times and under any circumstances filter successfully the

water of the Missouri River, wouldn't that filter at all times and under all circumstances filter with equal success the waters of the Illinois?

"A. I don't know. I should have to know more about the chemical compositions of the waters of the two rivers, at different seasons and times."

Prof. Keiser, for complainant, says the Missouri River water for eight months in the year ought to be rejected in its unfiltered state. It ought to be boiled anyhow or it might be boiled and filtered, too. (1134.)

Mr. Fuller, for complainant, testified as follows:

"Q. If there were typhoid bacilli in the Missouri River and the water supply of St. Louis was taken from the Missouri River only, there ought to be filtration or some treatment of that water?

"A. I should advise it.

"Q. If there were typhoid bacilli in the water of the Mississippi and the Missouri and the water supply of St. Louis was taken from those two streams, without the intermixture of the Illinois River water, it still ought to be filtered.

"A. In my judgment that is correct." (2630.)

Prof. E. G. Smith, for the defendant, testified on record 670 as follows:

"The waters of the Mississippi after receiving the waters of the Missouri are unsuitable to be used by the citizens of St. Louis for a water supply, in its raw state. I am of the opinion that the present treatment of the water by the settling basins merely, does not render the same a safe and suitable water for domestic and drinking purposes, to be used by the citizens of St. Louis.

"In my opinion, in order to render the waters of the Mississippi River safe after they have received the waters of the Illinois River at Grafton, and the Missouri River, at its

mouth, the same passing down by the Chain of Rocks, the proper method to treat that water would be by some process of efficient filtration.

"From my knowledge of the Mississippi River as based upon personal investigations and chemical and bacteriological examinations of the same, and from my study of the analyses of the Illinois River at Grafton, before the waters of the same are discharged into the Mississippi River water I am very clearly of the opinion that the cost of purification of water below the mouth of the Illinois River would not be increased owing to the waters of the Drainage Canal finding access to the river, and therefore the cost of installation and operation of a filter plant at the City of St. Louis would not be increased owing to the admission of waters from the Drainage Canal. From my knowledge of the quality of the Mississippi River water and the difficulties met with in successfully filtering the same; from personal studies upon filter plants and upon the river; the water of the Illinois River at Grafton being so similar to the waters of the Mississippi River; the waters of the Illinois River at Grafton being, in my opinion, essentially the same as they were before the waters from the sewage of Chicago were delivered from the Drainage Canal into the Illinois River, I am clearly of the opinion that the role which the Drainage Canal plays in the Illinois River would not affect the cost of installation, management or operation of a filter plant filtering the waters of the Mississippi River at St. Louis after the same have received the Illinois River at Grafton and the Missouri at a point below.

"The same general character as the Mississippi River water, I am clearly of the opinion that it would not cost any more to operate a filter plant or require more skill and expensive management of the same after the sewage of the City of Chicago had passed through the Drainage Canal into the

Illinois River and thence into the Mississippi River water above St. Louis than before the Drainage Canal was opened." (6791 *et seq.*)

Prof. Smith, the evidence shows, has made extensive examination of the water of the Mississippi River above the mouth of the Illinois in past years while engaged in the business of assisting in the erection of filter plants for municipalities along that river. In fact, his testimony shows that he has had more experience with filter plants on the Mississippi River and with the examination of that river than any other witness in the record.

Prof. W. P. Mason states that the water of the Mississippi River should be filtered. He also says:

"My opinion is that the addition of Chicago sewage via the Drainage Canal to the system of the Illinois River would not add any additional expenses to the purification of the Mississippi water by filtration at the Chain of Rocks. The installation and operation of the plant would not be greater in point of expenses by the addition of the Chicago sewage as it now is added to the system of the Illinois river." (6956.)

Rudolph Hering testified as follows:

"I have read the report made by a commission of hydraulic engineers upon the water supply of St. Louis, to the mayor of the city, in 1902. This commission consisted of Mr. Bennette Williams, Geo. Y. Wisner and Allen Hazen. My associate, Mr. Geo. W. Fuller, was asked to consider some features, and he made a report which is added to the report of the commission. I have read the report of Mr. Fuller that is published in the document to which I refer in regard to the question of filtering the water of St. Louis, as advocated by Mr. Hazen in that report. My personal views are that the water, in order to be supplied to the City of St. Louis for domestic consumption should be purified by mechanical or rapid filtration as the best, most rational and least expen-

sive method of purifying this particular water. In my opinion it would make no practical difference in the construction method or cost, nor in the method and cost of operation, to filter the water of the Mississippi River, at the Chain of Rocks, which consists of the combined waters of the Illinois, Mississippi and Missouri Rivers, with the sewage of Chicago emptying into the Drainage Canal, than it would if such sewage was eliminated from the sanitary Drainage Canal.

"The data which I have introduced in evidence would indicate to me that first and foremost a filtration of the water was necessary, due to the probability that typhoid bacilli would reach St. Louis to a large extent from the Mississippi and Missouri and to a less extent from the Illinois River. I should give no consideration at all to the sewage coming from Chicago because it is a small factor in the problem. It is too small a factor in the problem to materially affect any recommendation. The operation of such a filter plant would not require a higher degree of skill or more expensive men, with the sewage of Chicago emptying into the Illinois River than it would if such sewage was not present." (7006-7.)

John W. Hill, who is in charge of the filtration plant of Philadelphia, which is the largest in this country, and who has had considerable practical experience in the construction and operation of filters, testified as follows:

"In passing upon the question of filtering the water at St. Louis, no special consideration would be given the sewage of Chicago running into the head waters of the Illinois River, which forms one of the tributaries of the Mississippi River.

"It would make no difference whatever either in the cost of construction or the cost of operation of a system of filters for the City of St. Louis, whether the sewage from Chicago went through the Canal or was entirely eliminated.

"Of the three rivers contributing their water to the supply of St. Louis, the Missouri River would cause the largest pro-

centage of cost in operating a filtration plant, owing to the silt and suspended matter.

"The amount of infection in the river—meaning by that, sewage infection, would not create an added cost to the operation of filters.

"Assuming that a filter plant should be established at St. Louis sufficient in size and suitable for the demands required, the fact that the Mississippi River at the Chain of Rocks varied from time to time, from slight infection to great infection, would not create any added cost to the operation of such a filer. The degree of sewage pollution or infection of water coming to the filters would not be a factor either in determining their cost of construction or the cost of operation." (7558-7566.)

This evidence shows that the waters of the Missouri and the Mississippi Rivers independent of the Illinois River as admitted by witnesses for complainant are unpotable and that they should be filtered. The evidence further shows that in the event of a filtration plant being installed there would be no additional expense on account of the Illinois River emptying into the Mississippi.

28.

"COMPARISON OF TYPHOID FEVER DEATHS IN ST. LOUIS BEFORE AND AFTER THE OPENING OF THE CHICAGO DRAINAGE CANAL WITH OTHER CITIES."

This heading will be found on page 257 of complainant's argument. We have added in the latter part of this argument, a division under the heading of "Typhoid Fever" which answers complainant's argument under the above 28 subdivision.

29.

ACTUAL INJURY AND PERMANENT DAMAGE TO COMPLAINANT BY DEFENDANTS.

This is the last subdivision of complainant's argument and begins on page 260. It consists of the testimony in chief of Geo. W. Fuller and practically all the testimony offered by complainant on rebuttal, being the testimony of John W. Alvord, Dr. Herbert E. Smith and Prof. W. T. Sedgwick.

What has already been discussed in this argument, together with the additional subdivisions immediately following, entitled "Typhoid Fever" and "Purification of the Illinois River," we submit fully answers complainant's entire argument as well as this latter portion thereof.

TYPHOID FEVER.

Typhoid Statistics of St. Louis do not Correctly Show the True Typhoid Conditions in St. Louis in 1900.

The evidence shows that the mortality statistics of St. Louis are kept by the Department of Health by classifying under one head Typhoid Fever and under another head fevers styled Remittent, Intermittent, Typho-Malarial, Congestive and Simple Continued fevers. The evidence further shows that such a classification is improper, for the reason that a majority, if not all of the deaths alleged to have been caused by fevers enumerated under the head of Remittent, etc., can only be attributed to typhoid fever for the reason that the remittent, etc., fevers are never the cause of death, but are usually symptoms of typhoid fever. In other words the remittent, etc., fevers are not distinct types of fever, but are symptoms that accompany typhoid fever and a person suffering with only the remittent fevers would not die as a re-

sult thereof. Therefore placing them under this heading by the health authorities as the cause of death is incorrect. This is admitted by witnesses for complainant on cross-examination as well as testified to by eminent pathologists called by defendant.

The evidence further shows that a circular letter was issued by the health authorities of St. Louis to the physicians of St. Louis calling their attention to the fact that the law required them to report all cases and deaths from typhoid fever. This letter was sent out in 1900 and also in 1901. As a result of this letter the number of typhoid deaths as compared with those attributed to remittent, etc., fevers increased, and the number of reported deaths from remittent, etc., fevers decreased, showing a more correct diagnosis of the cause of death than had existed prior to the opening the Canal.

Prof. Jordan compiled from the Board of Health reports of the City of St. Louis a table showing the number of deaths reported for the years 1890 to 1903, inclusive, in the typhoid column, and the number reported in the remittent, intermittent, typho-malarial, congestive and simple fever column, these columns being referred to hereafter as columns A and B respectively. The table is as follows:

St. Louis.

(Population 1900, 575,238.)

YEAR.	Typhus Typhoid Fever.	Reported Deaths from Remittent, Intermittent, Typho-malarial, Congestive and Simple Continued Fevers.	TOTAL.
1890	140	226	361
1891	165	216	381
1892	441	326	767
1893	215	284	499
1894	171	179	350
1895	107	155	262
1896	106	177	283
1897	125	172	297
1898	95	134	229
1899	131	148	279
1900	168	112	280
1901	198	80	278
1902	222	102	324
1903	288	91	379

The Court will readily see by this table that prior to the year 1900 more deaths are reported under the remittent column than are reported under the typhoid fever column. Beginning with the year 1900 the reverse is true. 1900 was the year the Canal was opened. (6290 *et seq.*)

The evidence on this subject is quite voluminous and as the attempt made by complainants in rebuttal to refute it resulted in the physicians, whom they called, testifying on cross-examination to the same effect as witnesses for defendant, we do not deem it necessary to burden the Court with a review of it *verbatim*. We therefore state the facts and refer to the pages of the testimony on which can be found the evidence supporting the statements made.

The terms remittent, intermittent, typho-malarial, congestive and simple continued fevers are relics of old methods of description, which attempted to differentiate these febrile

about the same, I should say that the majority of those cases in the remittent, etc., column, belong in the typhoid column. If such a condition obtained, as evidenced by the compilation of the Board of Health of the city, I should say that the doctors in St. Louis were not employing the Widal test generally. It is the tendency that these practitioners wedded to calomel and quinine are obstinate in accepting new treatment for diseases. If the deaths are about equal from typhoid and all these other diseases, that proves it.

"I would say perhaps the typhoid column is as inaccurate as the other column. If the typhoid column is as inaccurate as the other column, I would attribute the inaccuracy to failure in diagnosis. The words, "remittent, etc.," are terms that have grown up but are not to-day employed by the advanced schools in medicine. Some of them are not recognized in the sense of being types of disease apart from the organism.

"It requires a great deal of skill among competent physicians to diagnosticate a case of malaria by the use of the microscope. The doctors in general practice in St. Louis are not possessed of that degree of skill necessary to make that diagnosis. That is true of typhoid fever. The fatality of typhoid fever depends largely upon the amount of germs taken into the system. The Widal test was introduced in St. Louis, I don't think to exceed six years ago. If it should appear that prior to six years ago there were more, or about an equal number of "remittent, etc.," deaths in St. Louis, as compared with typhoid deaths, the death rate column would not fairly represent the typhoid condition in my opinion.

"Assuming that a circular had been sent out from the Board of Health of St. Louis and that the public press was discussing the question of the effect of the Drainage Canal upon the water supply, and that the remittent, etc., fever column immediately decreased during the next three years and

changes merely on the basis of the symptoms which are most evident. They are not recognized by clinicians of the present time as being satisfactory names for specific types of fevers.

A large majority of the deaths placed in column B, or the remittent fever column, should be designated as typhoid fever and transferred to the typhoid fever column. Some of the witnesses testified that as much as 100 per cent. of the remittent, etc., deaths should be transferred to the typhoid column. These witnesses also testified that the letter sent out to the physicians of St. Louis manifested itself in the St. Louis typhoid fever statistics by causing an increased number of typhoid cases to be reported with a consequent decrease in the remittent, etc., fevers.

The witnesses testify that the two columns A and B should be consolidated together and upon being so consolidated show that in St. Louis after the year 1900 the typhoid mortality was about the same as prior thereto taking into consideration the increase in population. (Jordan, 6284-6310; Russell, 6547-6560; Hektoen, 6704-6710; Barker, 7090-7099; Vaughan, 7315-7328; Dock, 7045-7071; Smith, 7305-7307; Thayer, 7470.)

The following witnesses were called by complainant on rebuttal, they all being practicing physicians of St. Louis, and testified on cross-examination as follows:

Dr. Edward W. Saunders said:

"If it should appear in the Board of Health statistics of St. Louis during the last ten years, that they have a group of deaths reported as remittent, intermittent, typho-malarial, congestive and simple continued fevers, and those deaths amount to something like 200, I think the number is a reflection upon the doctors of St. Louis in their diagnosis of that character. That number of deaths, so characterized in the Board of Health report, reflects upon the diagnosis ability and carefulness of the doctors who make those reports. If the number of deaths appearing in the two columns were

that the typhoid column increased—if those are all the facts upon which I am to base a judgment, I would say that such an increase would be manifest in the statistics of the Board of Health." (7602-5.)

Dr. Washington E. Fischel testified on direct examination as follows:

"I believe that many cases of deaths from typhoid have not been reported as typhoid for the reason that if the physicians had reported these deaths as typhoid the Board of Health would have at once demanded an explanation of them why they had not been reported as typhoid before the death of the patient.

"If a doctor certified that one of his patients died of congestive fever, I should not know what to understand by that term. I should not consider the true cause of death to necessarily be typhoid. It might be something else besides typhoid. When a death is reported as caused by remittent or intermittent fever, it is not necessarily typhoid fever. It may be any of the diseases which have a fever as a symptom, such as consumption. You may have pneumonia with remittent fever. I should say that in my judgment there is no such thing as typho-malarial. The effect of the opening of the Canal has made me extremely careful of my diagnoses because, naturally, I felt there was great danger of the sewage of Chicago contaminating our water supply and I wanted to make it at least clear to myself whether in my experience that danger existed and therefore never reported a case as typhoid when the Widal test was not positive. I think the opening of the Canal has made the profession more careful in reporting deaths from typhoid fever to the Board of Health.

"At present I report no death as due to typhoid in which the Widal agglutination test has not been found positive. Previous to the issuing of the circular and the penalty which is conveyed to physicians neglecting to report typhoid cases,

the cause of death was frequently reported as typhoid when it might have been due to other diseases."

Cross-examination:

"The converse is true—that many deaths from typhoid were reported as other diseases, which should have been reported as typhoid, prior to the opening of the Canal. I know nothing definite about how to account for the number of deaths under the heading "Remittent, etc." I think many of the cases may have been tuberculosis.

"I think that the remittent, etc., deaths that appear in the Board of Health reports represent more typhoid than consumption. I think it is probably correct that the number of deaths as represented by typhoid would be a very small percentage of those prior to 1900 which would not be typhoid. I think the circular letter sent out by the Board of Health has made the physicians of this city more careful in reporting the typhoid cases.

"I think in regard to typhoid fever the chief reason for their having become more careful was the penalty attached by the Board of Health, in case physicians did not report typhoid fever. The number of deaths from typhoid fever may decrease or increase in a given community depending upon the skill of the physicians who are handling those cases, other things being equal.

"Many of those cases in the Board of Health reports of St. Louis under the heading "remittent, etc.," I would attribute to faulty diagnosis. I do not recognize those diseases as distinct types of disease. I believe it is true that those are terms which have grown up in the profession and are employed by doctors who are not up in the medical profession. When I find a number of deaths aggregating 200, in a city the size of St. Louis, reported under the head of remittent, etc., fevers, that certainly leads me to the conclusion that there

are a great number of doctors in St. Louis—the same as in any other city—who are not abreast of the profession." (7616-23.)

Dr. Ludwig Bremer testified as follows on cross-examination:

"Typhoid fever in St. Louis is not always distributed in all localities alike. It may appear in some localities more frequently and be absent in others. Such fevers as are characterized by the names "remittent, etc.," used to be recognized as distinct types of disease. They are not now. I would say that no doubt a number of these cases under the head of 'remittent, etc.,' are unrecognized or mistaken cases of typhoid. I do not know what percentage. It was from 1896 to 1900 that the water supply of St. Louis was suggested as being unsafe for drinking purposes in its raw state, and since then it has been kept up." (7628-33.)

Dr. Albert E. Taussig testified on cross-examination as follows:

"During ten years at least, it has been a wise precaution to boil and filter water in St. Louis, to prevent typhoid infection. The epidemic of 1892 caused a great many people to begin systematic boiling of water, who had not done so before.

"Under the head of 'remittent, etc.,' diseases reported to the Board of Health, I believe that some were typhoid, some consumption, some probably still other diseases. Assuming that 'remittent, etc.,' fevers was not the proper cause of death in such cases, such a diagnosis reflects upon the ability of the physicians sending in such causes of death.

"As to the words 'remittent, etc.,' I think it is likely that in the majority of causes in which these terms are used they are simply descriptive of the symptoms, but they may mean much more than merely typhoid and malaria. A great many

diseases might, upon a superficial examination, produce the same sort of an impression.

"Some of those terms, to my mind, cannot be called diagnosis at all." (7642-8.)

Dr. Chas. H. Goodman, testified on cross-examination, as follows:

"At times, it is a difficult matter for the very best doctors to diagnose a case of typhoid fever. I do not recognize remittent, typho-malarial, congestive and simple continued fevers, as distinct types of disease. These terms are characteristic of certain diseases rather than the disease itself. In the deaths reported to the Board of Health as "remittent, etc." those persons might have died of typhoid fever. They must have been confounding the terms, or they confounded the diagnosis of cases I should think. I do not know of any such fatality from malarial fever as would justify placing those deaths under the head of malarial fever. Considering that there are such a large number of deaths reported under the head of "remittent, etc.," in the years 1891, 1892 and 1893, I believe the doctors at that time reported cases of typhoid deaths under "remittent, etc.," deaths. (Statistics read to witness from 1894 to 1898, inclusive.)

"On the supposition that these figures were correct, I will say that the reports may have confounded diseases. Those that were reported as typho-malaria might have been typhoid, or typho-malaria, congestive, remittent or intermittent. These statistics cannot be accounted for in any other way than that typhoid fever has been wrongly diagnosed under those various headings. While the letter sent out by the Health Department in 1899 had no effect on me, I am not prepared to state that it had no effect upon any of the doctors who practiced in St. Louis. I cannot account for the increase in the remittent, etc., column of the statistics of the Board of Health for four years previous to 1900, and the in-

crease in the typhoid fever since the year 1900, in any way except that the fevers which have heretofore been diagnosed as intermittent, remittent, typho-malaria, congestive and simple continued fevers have been diagnosed as typhoid, and placed in the typhoid fever column, when prior to 1900 they were placed in the remittent, etc., column. If a letter was sent out by the Board of Health asking a report on typhoid fever, under penalty, I think the doctors would make reports accurately.

"I account for the large number of reported deaths for four years previous under the remittent, etc., column, and the small number since 1900, to mistaken diagnosis, that is, classifying those diseases, which were probably typhoid, under typho-malarial." (7666-76.)

As above seen we have only referred to the pages of the testimony of witnesses for defendants and have not quoted same. We desire to call the Court's attention to the fact that the testimony that is quoted above is that of complainant's witnesses, who were called in rebuttal and who upon cross-examination were shown to hold views in accord with those of the witnesses for defendant.

This shows that complainants introduced in evidence the typhoid statistics of St. Louis as issued by the Health Department as the basis on which all of their witnesses testify as to the increase in typhoid fever in St. Louis since the opening of the Canal. Defendants then took the same health reports and ascertained therefrom the number of deaths reported annually under the head of remittent, etc., fevers. Witnesses for defendant then testified that the deaths reported under the head of the remittent column were false diagnoses and should have been reported as typhoid fever. Complainant then introduced practicing physicians of St. Louis with the intention of contradicting the witnesses for defendant on this subject. A cross-examination of complain-

ant's witnesses having brought out the fact that they were entirely in accord with the view expressed by witnesses for defendant, complainants were then forced to seek to impeach the official records of the Health Department of St. Louis by the introduction of the testimony of Mr. Lochridge.

Mr. Lochridge testified that he examined mortuary records of St. Louis and he made a table showing the number of deaths from the various fevers under column B or remittent column of Prof. Jordan's table. This table is reproduced on page 331-2 of complainant's argument and notwithstanding the attempted corrections made by Prof Lochridge show that the average number of deaths from remittent, etc., fevers per annum prior to 1900 was 161, while for the four years beginning with the year 1900 they are 139. This still shows, according to complainant's own evidence that there are inaccuracies in the reporting of typhoid and other deaths to the Health Department of St. Louis, and that while the typhoid fever deaths reported subsequent to the year 1900 increased in number, the deaths reported from remittent, etc., fevers correspondingly decrease.

Take then the testimony of the physicians whose testimony was introduced in evidence by complainant in rebuttal and the testimony of Prof. Lochridge and they prove the contention made by defendants that the typhoid statistics of the Health Department of the City of St. Louis are inaccurate, do not show the true conditions and should not be relied upon. Yet these are the statistics that were used by all of the witnesses for complainant in making comparisons as to typhoid conditions prior and subsequent to the opening of the Canal.

We submit that if the statistics on which these witnesses base their opinions are inaccurate and do not show the true conditions, that the opinions of these witnesses so based on such statistics should have no weight in the determination of this case. The witnesses for complainant draw all their

conclusions from a report, which, by the testimony of Dr. Lochridge, a witness for complainant, on rebuttal, is shown to be inaccurate.

Prof. Jordan compiled a table (6304) showing the percentage of deaths to population in St. Louis for the years 1890 to 1903, inclusive. This table shows the percentage of deaths from typhoid fever alone in one column and in another deaths from typhoid fever plus 50% of the deaths attributed by the Board of Health reports to intermittent fever, etc., and also another column showing the percentage of typhoid deaths plus 100% of intermittent, etc., deaths.

In interpreting this table, Prof. Jordan said on record 6305:

"Assuming that the deaths reported under the heading typhoid fever alone during this period were the only deaths that occurred from this disease in the City of St. Louis, the average annual death rate from 1890 to 1899, inclusive, as shown in the detailed table, excluding, however, the year 1892, as being a year of special epidemic prevalence, was 28.8. On the same basis the average annual death rate from 1900 to 1903, inclusive, was 36.5.

"Assuming that only one-half of the deaths recorded under the heading intermittent fever, etc., were deaths from genuine typhoid fever, the average annual death rate from 1890 to 1899, inclusive, excluding as above the year 1892, was 46.07. On the same basis the average annual death rate from 1900 to 1903, inclusive, was 44.67.

"Assuming that all the deaths reported under the heading intermittent fever, etc., were deaths from genuine typhoid fever, an assumption which in my opinion is not very wide of the mark, the average annual death rate from 1890 to 1899, inclusive, excluding as above the year 1892, was 65.4.

"On the same basis that from 1900 to 1903, inclusive, was 52.1.

"On either of the latter assumptions the death rate from typhoid fever in the four years, 1900 to 1903, was distinctly lower than in the preceding decade, even when the year of maximum typhoid prevalence in that decade is excluded from the estimation.

"Q. Assuming that all the deaths in the typhoid column and the typho-malarial column are typhoid, how does the periods 4 years prior to 1900 compare with the period 4 years since 1900 as to whether there is an increase or decrease in the typhoid fever in the City of St. Louis?

"A. The annual death rate on this basis is almost exactly the same, being 52.2 for the period of 4 years prior to the opening of the Canal, and being 52.7 for the period of four years since the opening of the Canal. With these figures it would be impossible to assert that there has been either an increase or a diminution in the typhoid fever death rate in this period on the assumption just predicated.

"Q. Has typhoid fever increased or decreased in the City of St. Louis since 1900 over the conditions that obtained for the 10 years prior to 1900, in the City of St. Louis?

"A. It is emphatically my opinion that the average death rate from typhoid fever in the City of St. Louis has been less in the 4 years beginning with 1900 than the average for the preceding decade, excluding in this comparison the epidemic year of 1892." (6305.)

The above testimony of Prof. Jordan is based on facts, which are admitted to be the proper tests for such a compilation by witnesses who testified for complainant, *i. e.*, the transfer of the remittent, etc., deaths to the typhoid column.

Witnesses for complainant, Prof. Sedgwick, for instance,

instead of ascertaining the number of deaths per 100,000 population—shows the percentage of deaths from typhoid as compared to deaths from other sources. This is the method used by Mr. Fuller, quoted on page 263 of complainant's argument by which computation he comes to the conclusion that there has been an increase of 73 per cent. in the typhoid deaths in St. Louis since the opening of the Canal. A simple illustration will show to the Court that this method is an absurd one. For instance, if the typhoid deaths in 1899 were 100 and the total deaths from other causes were 1,000 the percentage of typhoid fever deaths would be 10 per cent. In 1900 if the typhoid fever deaths were still 100, but there were only 500 deaths from other causes, the percentage of typhoid fever deaths for 1900 would be 20 per cent., or an increase of 100 per cent., according to this method of computation. Yet in both years there were only 100 deaths from fever in this suppositious case.

That the complainant is compelled to resort to such distortive methods of deduction is a sufficient indication that the real facts do not sustain its contention. We submit that the proper method is to take the total number of deaths from typhoid per 100,000 population and in this manner the comparison of one year with another would be fair and reasonable. As above seen Prof. Jordan has done this with the result that no increase in typhoid fever is shown to have occurred in St. Louis since the opening of the Canal.

Prof. Russell testifies that taking into consideration the table prepared by Prof. Jordan "I should consider that the actual number of typhoid deaths, which have occurred in St. Louis since the year 1900 shows no increase over the death rate in that city from this disease for the period mentioned prior to that time with the possible exception of the recognized epidemic which occurred in the year 1892." (6559.)

Dr. Ludwig Hektoen testifies that the remittent and typhoid

fever column should be consolidated and that when so consolidated "the figures do not appear to me to show any increase in typhoid fever mortality." (6708.)

This witness also states that taking into consideration the table heretofore referred to, prepared by Prof. Jordan, compiled by adding together the typhoid and remittent column and taking into consideration the population of St. Louis, he comes to the conclusion that, "typhoid fever has decreased in the City of St. Louis since 1900." He states that he arrived at this conclusion by studying the figures in the table and that these figures show "that up to the year 1895, inclusive, the death rate from typhoid fever appears to be approximately 80 or 90 per cent., whereas, after 1896, up to the period 1900, it appears to be between 50 and 55 per cent., and between 1900 and 1903 the death rate is about the same." (6710.)

Prof. Barker testified that he made an examination of the health statistics of St. Louis and that they show there has been a transfer since the opening of the Canal of deaths from remittent to the typhoid column. He also states that these two columns should be added together to indicate the true condition. He states that from his investigation and consideration of vital statistics of St. Louis there has not been an increase in the typhoid death rate since 1900 and that the death rate in St. Louis is not excessive as compared with Baltimore and other cities. (7096-7.)

Dr. Victor C. Vaughan testifies that the typhoid and remittent deaths should be added together in order to accurately give the number of deaths from typhoid fever. Witness further states that when these two columns are so added together "If you take the years from 1890 to 1899, inclusive, you have total deaths of 3,708 for ten years. That would give an average death rate of 370. If you take the four years since 1899 it would give you 1,261 deaths or an average of 315 deaths

so there would be, if you included all the years from 1892 to 1903, inclusive, then the average would be greater before 1900 than since 1900. If you cut out the years 1892 and 1893 it would be smaller." (7323.)

This witness also states that the increase in typhoid fever, if any, in St. Louis is not such as would occur from a water supply, but is a gradual increase such as you might expect would be due from local conditions, especially as wells were getting more and more filthy and not condemned.

Prof. Geo. Dock states that the proper indication of typhoid condition should be arrived at by adding the typhoid and remittent fever columns, and that when so added they do not indicate a marked increase, "though they indicate a slight and gradual increase from the year 1898. An increase that I would explain partly from the fact that the diagnosis of typhoid fever has become broader all over the country. More cases are being included. There is a tendency everywhere to increase the proportion of typhoid cases in that way. There has been a slight and gradual increase." (7062.)

When asked to consider the table compiled by Prof. Jordan, this witness states:

"The table does not show that there has been a marked increase; on the contrary, a slight increase. Such an increase as I would ascribe rather to increased care in diagnosis, rather than to any outside conditions."

"Q. What effect would local conditions have upon an increase such as you have defined it to be?

"A. The figures are compatible with such slight increase, as we find here, and typhoid fever, in most places, like most other diseases runs cyclicly, without any fresh conditions from the outside or any marked condition in the matter of water supply or drainage. I should think in the last two years there would have been conditions in St. Louis, which would have increased the typhoid incidents. The fact that

many people were going there, people not accustomed to the climate, perhaps living carelessly, in nearly all such times we see such epidemics breaking out." (7065-6.)

This witness further states that he is of the opinion the wells in the City of St. Louis have quite an effect on the typhoid mortality. "My opinion is that the increase indicates rather a change in the conditions of the City of St. Louis itself rather than in the main water supply, supposing that the main water supply comes from a river. A change in the condition of the river water is always indicated in such cases by a more marked increase. As to such an increase as we have here, it is altogether compatible with changing local conditions such as wells, and the ordinary course of typhoid epidemics." (7066-7.)

Prof. Wm. S. Thayer testifies that the deaths reported under the remittent column are the result of improper diagnosis and should be added to the typhoid column, and that when so added the table would show "that the mortality from typhoid fever had varied from time to time, from year to year; had risen slightly during the last two years but that the fluctuations were no more than such as had previously occurred and were not such as would justify any direct assumptions in regard to the cause. * * * They are variations such as occur in most cities in this country from time to time without explanation." (7485.)

This testimony shows that if there has been an increase in typhoid fever in St. Louis it is but a slight one and is due to local conditions, for the reason that it was not explosive in its character, but is gradual. This record shows not only from the testimony of witnesses for defendants but from the testimony of all the witnesses for complainant, which has heretofore been reviewed in this argument, that where the water supply is infected with typhoid bacilli an increase in typhoid fever in cities using such water for their supply is

sudden and extremely large. No such large and sudden increase has appeared in St. Louis.

Dr. Teichmann, for complainant, testified that there was an epidemic of typhoid fever in November, 1899, and that there were 482 cases reported during that month.

"Q. No reason then has been able to be found for explaining the presence of typhoid at that time in St. Louis?

"A. Not to my knowledge.

"Q. And that was before the opening of the Drainage Canal?

"A. Yes, sir.

"Q. Since the opening of the Drainage Canal have you had as many as 482 cases of typhoid fever in St. Louis in any one month?

"A. No, sir.

"Q. Then the conditions in the public health of the City of St. Louis since the opening of the Drainage Canal has never reached the point in typhoid that occurred for any one month in 1899, is that correct?

"A. Based upon—

"Q. Can you answer that Yes or No, if it is true?

"A. If based upon the estimate of one month, you are right." (1689.)

Had the Chicago Drainage Canal been opened in the month of November, 1899, defendants would now be in a serious predicament in this case so far as St. Louis typhoid fever statistics are concerned, for the reason that complainant would have attributed the remarkable increase to the effect of the opening of the Canal. We can see now that had the Canal been opened in 1899 the increase in typhoid fever would have simply been a co-incidence. We submit that outside of any evidence to the contrary, and none has been introduced by

complainant in this case, whatever slight increase there may be in typhoid conditions in St. Louis (which supposed increase we deny), such alleged increase when considered in connection with the opening of the Canal is merely a coincidence.

The fact that there was a typhoid epidemic in the latter part of the year 1899 shows that the alleged increase of typhoid fever in St. Louis began prior to the opening of the Canal and was in no way caused thereby.

Prof. Sedgwick after being unable to state the cause of the increase in 1899 says that he has a simple explanation for the alleged increase in 1900, namely: the opening of the Drainage Canal. The testimony of Prof. Sedgwick is here quoted and needs no comment to show on what a slender foundation this "epidemiologist" can build an opinion.

He says:

"There is evidence that the outbreak at the end of 1899 reached over into 1900, as is seen in the fact that there were nineteen deaths in the month of January in the City of St. Louis from typhoid fever, a larger number than had occurred in that month for several years previous. On the other hand, it is very clear that the outbreak referred to had spent itself in February for the number of deaths from typhoid fever in St. Louis in February was lower than in any of the three years preceding; the number rises again, however, in March, being sixteen, a number larger for several years before in that month, and it might be thought by some epidemiologists, in fact I should myself have suspected if I had no other explanation of the fact, that these sixteen deaths meant a recrudescence of the previous outbreak. Fortunately, however, we have a simpler explanation in the fact that the Chicago Drainage Canal was opened on January 17, 1900, and it is in evidence, I believe, that not long after a mass of black and dirty water arrived at the intake of the St. Louis water works, which was believed to have come directly from

the Chicago Drainage Canal. In view of this evidence I regard the excess in March, or at any rate, the larger part of it, as due not to the recrudescence of the outbreak at the end of 1899, but to the pollution of the St. Louis water supply by material arriving from Chicago." (2396-7.)

An illustration of the pollution of a water supply causing typhoid fever, which is in point and bears directly on the conditions under consideration in this case is that of the epidemic that took place in St. Louis in the year 1892.

Dr. Ravold testifies that the cause of this epidemic was the passage of the sewage from Harlem Creek into the Mississippi River about 1,000 feet above the intake of the St. Louis water works, which was then located at Bissel's Point. The Court's attention is called to the fact that this is another illustration of an epidemic being caused by nearby pollution or infection. The distance in this case being nearly 1,000 feet. This epidemic due to the pollution of the water supply was explosive in its character and Dr. Ravold testifies on page 412 of the record as follows: "A great majority of the cases, 3,385, with 442 deaths occurred during the months of September, October, November and December, 1892, and January, 1893." He further states on the same page that in January, 1893, there were 114 cases and 42 deaths, while in February it dropped down to 35 cases and 18 deaths, the epidemic having by that time run its course. He further testifies that there were some 7,000 wells in the city at that time but that a thorough investigation was made and the fever was not discovered among the families who used the water. He also states that he went over the ice question thoroughly and also the milk supply, but that the epidemic was not due to those causes, but to the sewage running out from Harlem Creek right above the intake. (414-16.)

Here, then, we have the testimony of complainant's own witnesses, describing to us how an epidemic in St. Louis

affects the mortality statistics of that city when such epidemic is caused by the infection of the water supply.

Prof Ravold says:

"It was found that the typhoid fevers were uniformly distributed throughout the city and not around any particular well or wells—distributed independently of any well water." (414.)

The statistics also show on page 412 of the record that the deaths jumped from 4 in June to 15 in July, 11 in August, 23 in September, 48 in October, 124 in November, 205 in December, at which time the epidemic reached the climax, then down again to 42 in January, 18 in February and 7 in March.

The cause of the decrease of the epidemic is testified to by Dr. Ravold on page 410. He states that in November, 1892, in connection with some medical authorities an examination was made of Harlem Creek and a report was made to the St. Louis Medical Society and the attention of the Water Commissioner was called to it and he put a dam across Harlem Creek over 500 yards back from the river. Pumps were established and the water pumped from this Harlem Creek dam to a point below the intake of the water works. (410.) He said this was done after the examination made in November, but he does not remember the exact date. He states, however, "That was practically the end of typhoid fever there. There was little flurries following, but not to amount to anything, though." He also states that in that year there were 3,624 cases and 514 deaths, although the epidemic as above shown ran for a period of less than six months. It is safe to say that if the Harlem Creek had not been dammed these conditions would have continued indefinitely.

Compare this epidemic, which complainants allege to have been caused by an infection of the water supply, with the conditons prevailing during the year 1900 and we can readily see that the alleged increase since the opening of the canal is

not due to an infected water supply but must be due, as shown by the testimony heretofore quoted, to local conditions existing in St. Louis.

Complainant admits the increase of typhoid fever that took place in the year 1899 but lays great stress on the fact that the typhoid mortality was higher in March, 1900, than it was for March of any single year back to the year 1890. This fact is pointed out in several places in complainant's argument. We submit that picking out one month and comparing it with the same month in the years preceding it is an unfair comparison. Turning to the testimony of Prof. Ravold, beginning on page 419 we find the total number of cases and deaths by months for the years 1890 to 1900, inclusive, with the exception of the years 1893-4, which have been omitted and were to be inserted at a future time, but which we fail to find. The average number of cases occurring in November from the year 1890 to the year 1898, inclusive, excluding the epidemic year of 1892 and the years 1893-4, which are omitted is found to be 41 cases. The total number of cases reported in November, 1899, was 444, making an increase of over 1000 per cent. in the number of cases reported in November, 1899, as compared with the cases reported in any month of November preceding it. The average number of deaths for the same period is 15, while the number of deaths reported in November, 1899, is 27, making an increase of nearly 100 per cent. Yet, in November, 1899, the Canal was not open. The fact that the Canal was opened in January, 1900, is a mere coincidence. The unusual number and the enormous typhoid mortality, which is attributed to March, 1900, consists of 17 deaths. Seventeen deaths also occurred in January. As to the January deaths, however, complainants calmly pass that month by with the statement that those deaths still followed the epidemic of the latter part of 1899, which took place prior to the opening of the Canal. If deaths in January were due to

local conditions, why were not the deaths during March due to the same condition?

Counsel also passed the month of February without comment because the mortality from typhoid fever in that month is less than it had been for any February for ten years prior thereto. If the deaths in March are attributable to the influences of the Drainage Canal, why is it that in April we have only four deaths in 1900 as compared to five in 1899, and we also find that in May, 1900, we have three deaths; nine deaths in June and fourteen in July. (430-1.)

If the water supply of St. Louis was infected by the sewage of Chicago there would have been an explosive outbreak or epidemic of typhoid fever in St. Louis, beginning with the month of February and continuing without any fluctuation. This is what occurred when the water supply of St. Louis was infected by the sewage of Harlem Creek. The number of deaths increased month after month until the cause of the infection was removed. The alleged cause of infection in 1900 (the Drainage Canal) is still being operated and yet as above shown the typhoid mortality of St. Louis when correctly estimated shows no substantial increase.

We submit that the Court can take judicial notice of the fact that although the Canal has been opened nearly six years no typhoid epidemic has taken place in St. Louis. On the contrary, from reports of public officers of St. Louis given out to the public press it is shown that the water supply of St. Louis is now better than it was prior to the opening of the Canal.

Were the typhoid conditions in St. Louis due to the sewage of Chicago there ought to be a relationship between the number of deaths in Chicago and those of St. Louis. We will first refer to page 230 of complainant's argument, where a comparison is made between the deaths in Chicago and St.

Louis by years from 1890 to 1902, inclusive. The table referred to is as follows:

DEATHS IN CHICAGO AND ST. LOUIS.

Chicago

1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902
1008	1997	1489	670	491	518	751	437	636	442	339	509	801

St. Louis

1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902
277	160	488	215	178	106	106	125	95	130	168	198	222

(Record, Vol. 7, pp. 6901-3.)

The Court will note that in the year 1899, while there were 442 cases in Chicago, St. Louis had 130. In the year 1900 St. Louis increases from 130 to 168. If the conditions in St. Louis were caused by the dejecta of typhoid fever patients being deposited in the Chicago River thence in the Drainage Canal and into the Illinois and Mississippi Rivers respectively we would expect that an increase in St. Louis would follow an increase in Chicago. We find that this is not so, however, for in 1900 there were only 339 deaths in Chicago as compared with 442 in 1899, showing that the decrease in Chicago in 1900 was followed by an increase in St. Louis the same year.

Counsel also quote the following which is taken from page 6903 of the record and add "The foregoing affords no reason, excuse or cause for the increase at St. Louis subsequent to January, 1900" (complainant's argument, 228):

Total number of deaths reported from typhoid fever in cities lying tributary to the Mississippi, Missouri and Illinois Rivers, respectively:

	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902
Mississippi	321	285	240	200	257	237	217	261	291	210
Missouri	139	127	123	89	97	118	158	113	118	139
Illinois	45	62	45	65	56	66	55	129	85	82
Total	505	474	408	354	410	411	430	503	494	431

This table shows that subsequent to the year 1900 the typhoid deaths in cities lying tributary to the Mississippi in-

creased, as did those on the Missouri River, while those on the Illinois River decreased. This shows that if the typhoid fever in St. Louis is due to nearby infection that it is not caused by infection from the Illinois River. We respectfully ask the Court to consider the above two tables. A glance at the first one will show that there is no relationship between typhoid in Chicago and typhoid in St. Louis. The second one shows that the infection, if any, reaching the St. Louis intake must be from cities or villages or the deposit of typhoid dejecta in the waters of the Missouri and Mississippi Rivers nearer to the intake than is the City of Chicago.

We have heretofore shown under the heading of the longevity of typhoid bacillus that all of the epidemics referred to by complainants, or the defendants, were caused by rural infection or by the dejecta of one or two patients suffering from typhoid fever and in all cases this infection took place close to the intake of the water works, ranging in distance from a few feet to a few miles. We therefore submit that if the water supply at St. Louis is infected it is not infected by the sewage of Chicago but by infection coming from places nearer at hand.

Mr. Allen Hazen, a witness for complainant, testified as follows:

"If it should be shown that there was a general increase in typhoid over the Mississippi Valley co-incident with the increase in St. Louis, it would tend to show that the pollution from the cities up the valley contributed more to the increase in St. Louis and the addition of the Chicago sewage less, than I should suppose under opposite conditions. I have not given the question of the increase of typhoid fever for 1900 and 1901 in other cities outside of St. Louis any consideration. I understood that in some parts of the country cases of typhoid were brought into this country by soldiers of the Spanish-American war. I do not know what position St. Louis

occupied during those years, 1900 to 1902, inclusive, as to being a central point for returning soldiers from these wars, to separate and go to their homes." (2839.)

Dr. Ravold, a witness for complainant, testified that if there was a case of typhoid fever on any of the tributaries of the Illinois River and the dejecta was passed into the Illinois river that he could not tell whether the typhoid bacillus was from the tributary or from Chicago. He further said:

"Q. The effect upon a typhoid bacillus coming from the sewage of Chicago of dilution, sedimentation and the light, and the other causes that you have attributed for the disappearance of the typhoid bacillus, would render it less liable to inoculate anyone with the disease of typhoid fever than a bacillus that would come a distance of five or ten or fifteen or twenty miles, assuming that they were both equally virulent at the time they were discharged into the stream?

"A. In a patient of the same susceptibility?

"Q. Yes?

"A. The chances are that the bacillus traveling from Chicago to St. Louis would lose its virulency sooner than one that had traveled only a few miles." (866.)

However if we take the typhoid statistices of St. Louis as given in the Board of Health reports we will find that there is no relationship between the deaths in Chicago and the deaths in St. Louis.

Prof. Mason made a chart entitled:

"Deaths from Typhoid fever in 1900, 1901, 1902 and 1903, as reported in Chicago and St. Louis official Health Reports."

This chart is reproduced on pages 6926-7 of the record. We respectfully refer the Court to the record in order that a comparison may be made. Prof Mason when testifying in relation to these charts said:

"The deaths in St. Louis are stated one month in ad-

vance of those for Chicago, because of the length of time it would take a typhoid fever germ—should it go so far as St. Louis—to get there, because of the length of time that it would take to produce typhoid fever of fatal character after an invasion of the victim had taken place. In examining this chart and observing the fluctuations of the solid line representing deaths in Chicago and of the dotted line representing deaths in St. Louis, I observe that the two lines are by no means parallel.

"From an examination of the charts just presented I am of the opinion that no relation whatever exists between the typhoid fever as represented in Chicago and as represented in the City of St. Louis. In other words, I am strongly convinced that typhoid in St. Louis is not produced by typhoid fever in Chicago.

"It will be seen from an examination of those charts that the curves of typhoid fever are far from being parallel for the two cities. In many instances the rise of the curve from Chicago is coincident with the falling of the curve for St. Louis, particularly so for the month of August, 1902, when the typhoid in Chicago grows from 44 to 193 and the typhoid in St. Louis drops from 26 to 21." (6928-32.)

Prof. Theobald Smith testifies on record page 7301:

"If a typhoid bacillus was found at St. Louis, it would be utterly impossible to identify the source of such typhoid bacillus. The presumption would be that the typhoid bacillus would come from the nearest sewage discharging town."

Witness was then shown the charts above referred to by Prof. Mason and after examining same states:

"If it were true that a relation obtained between typhoid fever in Chicago and typhoid fever in St. Louis, I should think that the two curves of typhoid would be very much alike and the St. Louis curve would be slightly retarded in time. I am unable to see any direct connection between the typhoid

curve of Chicago and that of St. Louis from these diagrams. The upward curve in the St. Louis charts is one which seems to correspond with the usual summer and fall increase in typhoid, which is manifested throughout the civilized world, but I fail to see any direct relation between the two." (7303.)

He then states:

"Assuming that the typhoid conditions of St. Louis was due to the water supply, for the source of infection I should first look to the points nearer, by all means, and if these could be eliminated, then I think I should look to the City of Chicago.

"I think it would be highly important to locate the nearest sources first because of the vulnerability of the typhoid bacillus in water. The further the area of infection the less the danger of the typhoid bacilli reaching the water supply. A few bacilli discharged into a stream near by would be much more dangerous than a large number discharged at a much greater distance." (7304.)

The charts prepared by Prof. Mason, were examined by Prof. Vaughan, and he stated:

"These charts certainly would indicate that there is no casual relation between typhoid fever in Chicago and typhoid fever in St. Louis because if there was the charts should have the same general curve, charting the typhoid fever in St. Louis one month later than the typhoid fever in Chicago and such a relation is not shown by these charts.

"Q. If from a consideration of the typhoid conditions as they exist in St. Louis, as evidenced by the typhoid statistics assumed, both the typho-malarial and typhoid death columns you were called upon to attribute a cause for that typhoid condition where would you look for the cause?

"A. I should look for the case certainly in St. Louis in the local conditions."

"I think that there is no evidence so far as I can see from

these figures that the Drainage Canal has had anything to do with the typhoid fever in St. Louis for the following reasons:

"In the first place, as I have already stated, the distribution of typhoid fever in St. Louis as shown in these tables, is indicative of local contamination and spreading by contact rather than of any general water infection.

"In the second place there are certain cities in the list that I have given here where the increase in typhoid fever has been more marked than in St. Louis, and in these cases notably that of Buffalo, the drainage of Chicago has been turned away from Buffalo rather than to it.

"I think that there has been a gradual increase of typhoid fever throughout the country for the last few years, and the increase in St. Louis has been gradual. It has been slow and I do not think that there is any evidence from the figures that there has been any great contamination of the water supply of St. Louis. There has been no explosive outbreak of typhoid fever there." (7328-9.)

John W. Hill, when shown the charts in question stated:

"If the typhoid fever statistics of St. Louis show an increase in the rates per unit of population since the opening of the Drainage Canal and the investigation clearly indicates that there is no other possible source of infection and the rates in St. Louis rise correspondingly with the rates in Chicago and fall correspondingly with the rates in Chicago, it might be held that such increase in the unit rates for typhoid fever in St. Louis could be charged to the flow of sewage through the Drainage Canal, but in view of the possibility of infection from other urban centers than Chicago, and especially in view of the possible infection of the St. Louis water supply from typhoid fever prevailing in Peoria, I should hesitate to charge to the flow of Chicago sewage through the Drainage Canal any increased typhoid rates

shown in the City of St. Louis since the opening of the Canal unless the evidence clearly disclosed the fact that as the rates raised in Chicago they raised in St. Louis and as they declined in Chicago they also declined in St. Louis. In other words, unless the rates in St. Louis showed that they corresponded with the rates of the city supposed to be the cause I am lead to this opinion by the much nearer source of infection in the City of Peoria, where typhoid fever prevails during the usual season of typhoid and doubtless is found prevailing to some extent throughout all the months of the year. Or, in other cities of large population upon the water shed of the Mississippi and Missouri Rivers. While one can not positively say that the sewerage of Chicago might not contribute to this, it is equally out of the question to assert that a single city discharging its sewerage into one of the rivers constituting the drainage area of the river which went in front of the St. Louis intake is the sole cause or at all the cause of the increase of rates in the City of St. Louis. Too many factors enter into the proposition such as is contained in the question to justify one in asserting that typhoid fever is due to any one of the several possible centers of infection lying on the drainage basin above the City of St. Louis.

"Q. Assume that the City of St. Charles located within 47 miles of the intake tower of the St. Louis water works containing a population of 7,000 with more typhoid fever present than in the City of Peoria, which City of Peoria is located 286 miles above the City of St. Louis, what would be the comparative effect of these two cities upon the water supply under the conditions assumed?

A. The smaller city, namely, St. Charles, being nearer the point of intake above the City of St. Louis in my opinion would constitute a greater menace to the water supply of that city than would the larger City of Peoria, situated five times as far away in point of distance from the intake of St. Louis

even though the normal rate of typhoid fever were the same in the two cities. I have always believed and can point to no evidence that contradicts this belief, that the nearness of the point of infection rather than the size of the urban or rual center is the chief factor in determining infection. That the little city near by in which typhoid fever prevails is more to be feared than a large city far distant even though the same unit rate of typhoid is found in each.

"A. An examination of the diagrams for the year 1900 to 1903, inclusive, in which the solid lines show the charted deaths by months for the City of Chicago and dotted line the same data for City of St. Louis for each of the years embraced, and which in the legend at the top of each of the pair of diagrams a statement is made, and considering the statement in the legend at the head of the two pages before me, showing that the deaths in St. Louis are platted one month in advance, nameiy that February deaths are platted as of January, presumably for the purpose of comparison of the deaths in St. Louis directly with the deaths from typhoid fever in Chicago, it does not appear that the typhoid fever death rate from St. Louis are coincident in intensity with the typhoid fever death rates of Chicago. This is especially true for the years 1901 and 1902 and 1903. For which years the diagrams show that when the rate is rising in Chicago it is declining in St. Louis and when it is declining in Chicago it is sometimes rising in St. Louis, and that the wide ranges in typhoid fever death rate as shown in the diagram for the City of Chicago are not reproduced in the diagram showing typhoid fever death rates for the City of St. Louis, and it would not be possible in my opinion to connect the rates in one city with the other. In fact there might be just as close an agreement between the typhoid fever rates of the city as there is between the typhoid fever death rates of the Cities of Chicago and St. Louis and clearly the typhoid fever rates of Chicago can have in this

manner no influence whatever upon the typhoid fever rates of Philadelphia. There is nothing on the face of the four diagrams to indicate a connection between the typhoid fever death rates of the two cities." (7554-5-6-7.)

Professor Jordan states that he has prepared a table of death from typhoid in Chicago and St. Louis by months from January, 1890, to December, 1903, inclusive. These tables are reproduced on pages 6279-80 of the record. This witness testifies as follows:

"From these tables, I am unable to discover any relation between the monthly deaths from typhoid fever in Chicago and those in St. Louis. An increase in the death rate from typhoid fever in St. Louis is not preceded by a corresponding increase in the death rate in Chicago. A decrease in number in Chicago is not followed by a decrease in number in St. Louis.

"If typhoid fever in St. Louis during that period was caused by infection coming from Chicago, I should certainly expect to find some relation obtaining between the prevalence of this disease in Chicago and that in St. Louis.

"I should anticipate that in general if the typhoid fever conditions in St. Louis were dependent upon those in Chicago that a large number of deaths from typhoid fever in the latter city would be followed within three or four months by an increase in the number of typhoid deaths in St. Louis.

"No such relation appears in the monthly records of typhoid fever of these two cities as tabulated.

"It is therefore my judgment that typhoid fever conditions in St. Louis are unaffected by a large amount or small amount of typhoid fever in Chicago.

"(Witness refers to water gauge readings at Kampsville, Illinois, of which tables have been made.)

"From an examination of the tables just referred to, I am

unable to discover any connection between the stage of low water as disclosed in the gauge readings at Kampsville, and a large amount or small amount of typhoid fever in St. Louis. In the four years for which record is at hand, absolutely no relation exists between low water in the Illinois River as shown by the gauge readings at Kampsville and an increase or decrease in the typhoid mortality in the City of St. Louis.

"From an examination of the monthly deaths reported from typhoid fever in Chicago and St. Louis between 1890 and 1903, inclusive, I am unable to discover any dependence of the mortality in St. Louis upon that in Chicago, as respects extent of mortality, season of the year or stages of water in the Illinois River." (6281-4.)

This testimony shows that if the mortality statistics of St. Louis are properly interpreted as admitted by witnesses for complainant they should be, it will be seen that there has been no increase of typhoid fever in St. Louis since the opening of the Canal.

If we take the figures, however, as submitted under the heading of typhoid fever alone, the increase shown is only such an increase as has taken place in many other cities in the United States during the same period and is not due to the influences of the Drainage Canal for the reason that the increase is gradual instead of explosive in its character. The increase is also such as would naturally be expected from local conditions existing within or nearby St. Louis.

Be that as it may we submit to the court that if complainants have shown an increase in typhoid mortality in St. Louis they have failed to show that such increase is due to the sewage of Chicago reaching the St. Louis intake. We submit that the evidence shows that the longevity of typhoid bacillus entering the sewers of Chicago is much less than the time required for the water to make the journey to St.

Louis. We submit that no witness has shown that typhoid bacilli from Chicago can reach the intake at St. Louis in a virulent condition.

We submit that the experiments that have been made in this case on the longevity of typhoid bacillus and also the testimony that has been introduced in regard to the chemical and bacteriological conditions of the Illinois River demonstrate that typhoid bacteria from Chicago cannot reach as far down the Illinois River as Peoria. In this connection we respectfully suggest to the court to consider this argument under the heading "Purification of Illinois River."

The burden of showing that typhoid bacilli reach the intake at St. Louis from the sewers of Chicago is upon complainant. Complainant, however, has failed to make such proof. The only evidence on this subject being bare statements to the effect that the witnesses are "inclined to believe" that typhoid bacteria "might probably" reach the St. Louis intake for the reason "that that is the easiest explanation."

PURIFICATION OF THE ILLINOIS RIVER.

Under this heading we will discuss the purification of the Illinois River and also will refer to the testimony showing conditions before and after the opening of the Drainage Canal.

This subject will be treated under two separate heads. First, the scientific testimony, and, second, the lay testimony.

Effect of Opening of the Canal as Shown by the Scientific Testimony.

Professor John H. Long has been the Chemist of the Illinois State Board of Health since the year 1885. He made an examination of the Illinois River in the year 1886, also

in the year 1887-8-9. As to the examination made in 1886 the analyses being introduced in evidence on page 4028 of the record, the witness states:

"These analyses show beyond any question a very marked destruction of organic matter in the flow between Bridgeport and Peoria, showing the effect of what is called bacterial oxidation in an extremely marked degree, the water at Peoria in that particular season being practically potable and actually used by a large number of people. I was at Peoria during the season and observed that fact myself. That was in the summer of 1886. This effect is partly of course due to the oxidation and also to the dilution from tributaries, but the largest part of the effect is unquestionably due to actual destruction by bacterial oxidation." (4030.)

The averages of examination made in the winter of 1886-7 are testified to on page 4030 of the record. The witness then states:

"The conclusion I draw from these averages is that in the winter of 1886-7 as in the summer of 1886, there is a very considerable destruction of organic matter in this stretch between Bridgeport and Peoria, but the destruction or oxidation is much less marked and characteristic than in the summer, as is always the case in these observations." (4031.)

As to the chemical analyses made in the years 1888-9 the results are testified to on pages 4031 to 39, inclusive, the witness stating:

"These results show a purification of the river between the source of the water at Bridgeport and the outlet of the Illinois River at Grafton. The purification measured by the destruction of organic matter, showed a very great or a very marked diminution of the organic matter. This diminution of the organic matter is due to two principal factors—the dilution of the stream by the water from various tributaries,

and to the destruction of the organic matters by the oxidation, using that term in a general sense, or broad sense. The disappearance of organic matter is very much more marked than is the dilution, as indicated by the change in chlorines, the condition being finally reached in which the organic matters are not larger or greater in amount than in the tributary streams, and are not larger in amount than in the streams commonly found in that part of the country."

During this time an examination was also made of the tributaries of the Illinois River, the results of the examinations in the shape of tables being reproduced on pages 4041 to 4071 of the record. The witness then testified as follows:

"The consideration of these tables which have been referred to and given by me, and the comparison of the results of the analyses of the Illinois River at its mouth, with the results of the analyses of the tributaries of the Illinois, indicate that a condition of organic purification of the Illinois at its mouth has been reached, which is comparable with or similar to that found in the tributaries mentioned. As indicated by the various tests which have been described, the organic matters in the Illinois River have been reduced to a point where they are not larger in general than the organic matters found in the several tributaries. They have been reduced to a point beyond which the destruction of organic matter in the river by natural means can not practically be exceeded or surpassed. Apparently the limit of oxidation of the organic matters has been reached. We have here a condition in which the organic matters have been broken down and destroyed largely, and the residues that are left, not destroyed, are of a stable type, very resistent to all oxidizing influences. A condition characteristic of organic matter of vegetable rather than animal origin, from which I conclude that in general these organic matters must be attributed to the leechings of the soil, that is to products of vegetable

origin rather than to the products of animal origin. This condition obtains in all the rivers to some extent and in the Illinois River at its mouth and its tributaries.

"The organic matter in the Illinois River at points far above its mouth, is in general larger than the organic matter in most of its tributaries, but by the time the mouth of the river has been reached, the organic matter has become so far reduced that it compares in general very closely with that found in the tributaries, and does not exceed that in the tributaries in general. In most of the examinations the condition of the water at Upper Peoria or Averyville, as it is sometimes called, is very analogous to that of the tributaries. There is a purification of the organic matter there so that the water corresponds closely to the water of the tributaries. These answers are all directed to the period of these examinations. The water of the Illinois River at Grafton in this season, in the summer of 1888, has reached a degree of organic purity fully equal to the mean condition of the waters in the tributaries mentioned, the DuPage, the Kankakee, the Fox, the Big and Little Vermilion and the Sangamon. In drawing these conclusions I have taken into consideration essentially these three factors, the amount of free ammonia, the amount of albuminoid ammonia and the figure representing the oxygen consumption. I have also considered the condition of oxidation as shown by the amount of nitrates, nitrogen in nitrates. There are four elements in reality going to make up this conclusion and by comparison of these four elements, it has been shown that the Illinois River has reached a condition of organic purity comparable with the tributaries. (Witness gives a comparison of averages of chemical elements from which he has formulated his opinion, for the tributaries of the Illinois and at the mouth of the Illinois River.)

"The average of all of these results from all of the rivers will show a condition of organic impurity as great as that of

the Illinois at its mouth. (Witness explains reasons for his belief.) Am acquainted with the Illinois River and its tributaries from personal knowledge by actual observation at various times. Have personal knowledge of the sources of sewage contamination entering the Illinois River and its tributaries from an examination of many points along said river and its tributaries." (4072-5.)

Referring to table giving results of examination in 1889 Professor Long says:

"This table giving the summary of the analyses made during the winter of 1888 and 1889, shows a considerable reduction of organic contamination of the water between Bridgeport and Grafton, but a very much less marked degree of reduction than was observed in the summer of 1888. * * * The condition indicated by the figures for oxygen consumption is also one of increased organic contamination. The explanation of this is not difficult and should be given here.

"During the summer season in the stretch between Peoria and Pekin, which is a nearly level stretch of eight or ten miles in extent, an enormous decomposition of organic matter occurs, as is observable in passing through the stream. This decomposition is a bacterial or fermentative decomposition, as disclosed by the rapid evolution of gases in this part of the stream, so that roughly, this stretch may be compared to a great septic tank in which hundreds of tons of organic matter are undergoing decomposition all the time. The rate of decomposition of organic matter varies as is well known, by temperature. In the winter season therefore, we have this rate very much slower, so that at Pekin, below the distilleries and cattle sheds of Peoria, the enormous pollution as indicated by the residual albuminoid ammonia factor and the factor for oxygen consumption indicates fresh and recent additions. The consideration of these figures shows beyond question whatever, that the addition of filth at Peoria is a very

important factor in accounting for the organic matter in the river below. I am confining my answer to the period of 1888 and 1889, and not to a date subsequent to that time.

"The comparison of the results obtained in the Illinois River in 1886, with those obtained two years later, 1888-1889, indicate increased pollution of the Illinois River at Peoria. From personal observation of the Illinois River at Peoria in 1886, I know that the water was potable, and formed a large part of the water supply of Peoria. From personal observation I know that later this water supply was abandoned because of the increasing pollution of the river, which was shown also by the analyses. For 1886 the point farthest down the river for which I have analyses is Peoria." (4079-4100.)

This testimony, based on examinations carried on for a period of over 15 years, shows that the Illinois River, owing to its peculiar physical characteristics, purified itself of the Chicago sewage deposited in it through the Illinois and Michigan Canal.

We submit that the bacteriological and chemical analyses made in the year 1899 and subsequent thereto show that the opening of the Chicago Drainage Canal did not change the purification process taking place in the Illinois River from what it was prior thereto. In fact, the following evidence will show that since the opening of the Canal the Illinois River still purifies itself of the impurities discharged therein by way of the Drainage Canal long before the City of Peoria is reached, which is about 160 miles from Chicago, the samples of water having been taken at a point just above the City of Peoria called Averyville.

It must be remembered by the court that the distance from Averyville, where this purification has taken place, to Grafton, Illinois, at which is located the mouth of the Illinois River, is 161 miles, and from Grafton to the St. Louis intake is 43

miles. This shows that while the Chicago sewage is purified in a run of 159 miles from Chicago to Averyville, it must still travel 202 miles after leaving the point at which it has reached a state of purification to the St. Louis intake.

In fact, the evidence which we quote under this heading shows that the water flowing in the Illinois River purifies itself twice in its flow to Grafton. After leaving Averyville the evidence shows that the sewage from Peoria and Pekin again pollutes the water. The evidence further shows that by the time it has traveled another 150 miles to Grafton it has again purified itself and is as pure as its tributaries, which are not affected by the Drainage Canal, and purer than the Mississippi River, into which it flows.

An extensive examination was made of the Illinois River beginning with April, 1899, nearly one year prior to the opening of the canal, by chemists and bacteriologists representing the Illinois State Board of Health, the Board of Health of the City of Chicago, and the Sanitary District of Chicago.

During the investigation of 1899 the samples were taken weekly. The tributaries of the Illinois River were also examined in 1899. (4121.) The results of these chemical examinations were made up into tables and reproduced on pages 4130 to 4157, inclusive, of the record.

Professor Long in testifying about these tables says:

"From a consideration of the tables presented and from the tables of averages drawn from these individual tables, these general conclusions may be reached:

"First: That the first and most general examination of this table shows a very great diminution in the organic pollution of the Illinois River and its tributaries, and the source between Bridgeport and Upper Peoria or Averyville, a diminution of the organic matter which cannot be accounted for by the dilution from the tributary waters as shown approximately by the decrease in the chlorine contents. This de-

crease in organic matter is explained by a consideration of several factors. We find in considering data given for oxygen absorption or oxygen consumption in the filtered water as well as in the unfiltered water, that between Bridgeport and Peoria there is a very marked decrease, a point being reached finally where the organic matter as disclosed by the oxygen consumption test does not appreciably differ from that found in the tributaries of the Illinois as shown by the same test.

* * * * *

"A very noticeable feature of these tables is that after Upper Peoria or Averyville, or the Peoria Narrows, is passed, the condition of the river as disclosed by the analyses shows a very marked organic pollution again. We find that below Peoria the amount of organic pollution as measured by the albuminoid ammonia is very nearly as great as that observed in the Canal at Bridgeport. We find also in passing Peoria that the free ammonia has increased from less than one part per million to over four parts per million. We find also that the figures measuring the oxygen consumption in passing Peoria have increased in the case of the unfiltered water from over six parts per million to over 17 parts per million, and the figure indicating the oxygen consumption in the filtered water has increased approximately from five and one-half parts per million to nearly thirteen parts per million. This remarkable increase in the numbers given shows that at this point a very great amount of organic matter has been added to the Illinois River. From the investigations which I have myself made at different times, an explanation of this increase is given. It is a matter of personal investigation and also of common knowledge that in the City of Peoria there are great industries which discharge waste of a highly organic nature into the Illinois River and the samples of water collected at Wesley were taken from a point below the discharge of these industries. These industrial wastes are mainly from distilleries and from cattle sheds in which cattle feeding on

the slops of these distilleries are kept, and from glucose factories. Coming down the river from Peoria we observe again, as we did in coming down from Bridgeport to Peoria, a very marked gradual decrease in organic contamination. This decrease is observed in a gradual fall in the figures indicating the oxygen consumption in the filtered and unfiltered water and in the free ammonia and the albuminoid ammonia so that a change takes place in the Illinois River below Peoria, and is due to the same general causes, as indicated by the amount and character of the products given here, as takes place in the river above Peoria, so that finally at the mouth of the river at Grafton, we have reached a condition in which the factors for organic pollution are not greatly different, or essentially different from those observed in the tributaries of the Illinois River. Taken as a whole, then, these tables disclose two main sources of contamination of the Illinois River, first, the sewage from the City of Chicago, which decreases very greatly before Peoria is reached, and secondly, the industrial wastes from the City of Peoria, which decrease greatly before the mouth of the river at Grafton is reached. A consideration of these figures shows beyond any question whatever that the main factor in contamination of the Illinois River at its mouth is not the waste or sewage contributed from Chicago, but the industrial waste contributed from the various industries of the City of Peoria.

"In comparing the results of the analyses made for the Canal and the Desplaines River at Joliet, and the obtained analyses of the Illinois River water at Wesley, we see that the number for the albuminoid ammonia is greater at Wesley than it is at Joliet, indicating a larger amount of protein products, decomposable in the albuminoid ammonia distillations at Wesley, than is found in the Des Plaines River and Canal at Joliet. We have also the albuminoid ammonia at Joliet, being measured by 2.88 per million, while that at Wes-

ley is measured by 3.2 per million. This average being drawn from individual experiments which are comparable in time and number. It is seen from comparing Joliet with Wesley that we have at Wesley, as indicated by the oxygen consumption, an amount of organic matter almost as great as at Joliet, in the filtered water. In the filtered water of Joliet, the oxygen consumption being 15.1 parts per million, while at Wesley it is 12.84 parts per million. In the water not filtered the oxygen consumption number is 25.9 parts per million at Joliet and 17.44 parts per million at Peoria. As the waste of Peoria is known to be largely of a nitrogenous character, this difference in the numbers is simply and easily accounted for, the oxygen consumption number being relatively greater at Joliet, and the albuminoid ammonia numbers being relatively greater at Peoria; the albuminoid ammonia numbers measure most fairly the protein condition of contamination.

"The comparison of the water at Joliet with that at the Peoria Narrows is very instructive, the condition of the water at Joliet in every way being much worse than that at the Narrows. In my analyses the numbers given for oxygen consumption and for free ammonia and albuminoid ammonia, indicate at Joliet a very highly polluted condition, such as we find in the waters of marked sewage contamination, while at the Peoria Narrows the numbers given for oxygen consumption and free ammonia and albuminoid ammonia are not greatly different or essentially different from those which are found in the waters of the ordinary streams of the State of Illinois, not unreasonably contaminated, or not contaminated with anything more than is taken up by the passage of these waters through a soil rich in ordinary organic matters.

"In the case of the albuminoid ammonia figures, the amount in the Fox River at Ottawa is almost as great as that of the

Illinois River or Canal, both figures being in the proportion that we find in the ordinary streams of the State of Illinois, flowing through soil containing a large amount of organic matter. By a consideration of the figures given for the analyses of the Illinois at La Salle and at Pekin, these relations are observed: The organic matter as indicated by the albuminoid ammonia at Pekin is very much greater than the organic matter indicated by the albuminoid ammonia at La Salle; the amount of free ammonia at La Salle on the contrary is greater than the free ammonia found at Pekin.

"That indicates that the oxidation of the free ammonia at La Salle has not gone as far as the oxidation of the ammonia at Pekin. In the case of the contamination as measured by the oxygen absorption, the condition at Pekin is very similar to that at La Salle, the numbers being nearly the same. In comparing the waters of the Illinois River at Peoria and the Peoria Narrows, and Grafton, we find as measured by the oxygen consumption figures and by the free and albuminoid ammonia figures somewhat more organic matter indicated at Peoria than at Grafton, but not a great deal more. As indicated by the oxygen consumption test, the Mississippi River water at Grafton contains more organic matter than the Illinois River water at Peoria Narrows. As indicated by the figures for free ammonia, oxidation has gone very much further in the Mississippi River at Grafton than at the Narrows at Peoria. As indicated by the albuminoid ammonia test, the organic matter in the Missississsippi river at Grafton is about eighty per cent. of that in the Illinois River at the Peoria Narrows. As measured by the oxygen consumption test, the Mississippi River water at Grafton contains more organic matter than the Illinois River water at Grafton. As measured by the albuminoid ammonia, the Illinois River at Grafton resembles very closely the Mississippi River water at Grafton.

"The other determination shows that in the Illinois River water at Grafton we have evidence of a large amount of nitrogenous matter which has undergone oxidation. Nitrites, for example, at Grafton, or the Illinois River at Grafton, being nearly twenty times as great as the nitrites in the Mississippi River water at Grafton. We have also in comparing the Mississippi with the Illinois River at Grafton this fact, that of the unoxidized ammonia we have in the Illinois River about three times as much as in the Mississippi River water. From a consideration of all these tables and averages, the conclusion is a necessary one, that the organic matter discharged at Bridgeport into the canal and subsequently into the Illinois River, has undergone practically complete oxidation before the mouth of the Illinois River is reached at Grafton, because at this point we find no more organic matter than can be accounted for readily by that discharged from the tributaries and from the contamination at Peoria.

"I have testified as to the chemical results of the 1899 investigation. The bacterio-chemical results agree in a general way with the chemical results, in showing the condition of extreme organic contamination at Bridgeport, Lockport and Joliet, which show gradual improvement as we go down the river until Peoria is reached—Upper Peoria or the Narrows, or Averyville, as it is called, where the individual results obtained by the various methods which I referred to this morning do not differ essentially from similar results obtained from the tributaries of the Illinois. But leaving Peoria Narrows and going down to Wesley, we find as indicated by these bacterio-chemical results, great marked increases of contamination again. The number of forms of organic matter in the organized condition, or living condition at Lower Peoria or Wesley as disclosed by what is called the colony count, is certainly as great as that found at Bridgeport, while the factors indicating the fermentation of carbo-hydrates by the bacteria present and indicating the presence of those bacteria

which convert carbo-hydrates into acids and coagulate milk, are likewise as great at Wesley as at Bridgeport, so these bacterial results then in general agree with the chemical results in showing an enormous increase in pollution as Peoria is passed, and these chemical bacterial results show as we leave Peoria and go down the river, a gradual diminution in the organized forms until the mouth of the river is reached at Grafton, where the number of bacteria present, and the behavior of the bacteria with the re-agents mentioned, show a condition similar to that found in many of the tributaries of the Illinois." (4160 *et seq.*)

Tables were then introduced in evidence showing the result of the examination made in 1900. These tables are reproduced on page 4171 to 4181 inclusive and show results of examinations made in the spring of that year.

As to these tables Professor Long says:

"From these various tables I note that the amount of organic matter at Bridgeport in the old canal and the Drainage Canal at Western avenue is less than disclosed by the previous analyses given in 1899. An exact comparison is however difficult because of the fact that in this period (in the spring of 1900), the water flowed through both canals, through the Illinois and Michigan Canal and through the Drainage Canal, but not at a constant rate, so that an exact comparison of these figures is difficult. However, as we proceed down the river to Morris, where there is a complete mixing of the waters, we find for the numbers representing the free and albuminoid ammonia a lower amount than disclosed in the analyses made in 1899. When Lower Peoria or Wesley is reached, there is here a very great increase in the figures for all constituents. In the factor representing the oxygen absorption, the free ammonia and the albuminoid ammonia the increase is very marked. Following below Peoria we observe a decrease in these factors, representing or pointing to the amount of organic mat-

ter present. We find at Pearl that the factors for oxygen consumption and for albuminoid ammonia are as low as in the 1899 examinations in general, and as low as disclosed in the waters of many of the tributaries of the Illinois. We find at Grafton, however, below Pearl, for some reason which cannot be given, a slightly larger amount of organic matter in the mean, than at Pearl, but the point of greatest importance in this table is the very marked increase of the organic matter at Peoria and at Wesley, the point below Peoria, as compared with the amount found at points above during this same examination. A comparison between the waters at these points is a fair one because they were collected through the same months and shows this: that at Wesley, below Peoria, the organic matter as measured by the oxygen absorption and by the albuminoid ammonia and as indicated also by the results of the bacterio-chemical examinations, is greater than that found at Morris through the same period. Any increased dilution below Morris would tend to decrease rather than increase the contamination at Peoria, making it appear even more strongly. The organic matter is larger than at Morris. At Grafton, the various factors given in the table show a lower condition of contamination than at Morris, in practically all cases. At Morris in 1900, after the opening of the Drainage Canal the amount of albuminoid ammonia is very much less than the amount found in 1899, before the opening of the Drainage Canal. The factor for oxygen consumption in 1899, is, in the filtered water somewhat greater than for the filtered water in 1900, but for the unfiltered water, slightly less.

"That indicates simply as stated, that the amount of organic matter is less one year than the other, to make that direct comparison. At Wesley, in 1899, in the mean, as indictated by the albuminoid ammonia, there was more organic matter present than in 1900, as indicated by the oxygen consumption; also somewhat more in 1899 than in 1900. The

free ammonia at Wesley in 1899 is greater than that at Wesley in 1900. It contains less pollution in 1900 than it showed in 1899. At Havana, in 1899 the amount of organic matter as measured in parts per million by the free and albuminoid ammonia was greater than in 1900, and the oxygen consumed shows a somewhat similar condition. The oxygen consumed is a little greater in the spring of 1900 than in 1899. As measured by the albuminoid ammonia, in a given volume of the water, the analyses showed that there is a greater pollution in 1899 than in 1900. While, as measured by the oxygen consumption the result for 1900 appears to be slightly greater than the result for 1899.

"At Pearl, as measured by the oxygen consumption, the organic matter in parts per million is greater in 1900 than it is in 1899, but as measured by the albuminoid ammonia present, the contamination in 1899 is greater than that in 1900. Comparing the river through the summer of 1899 at Grafton, with that at Grafton through the spring of 1900, we find that the condition at Grafton shows more organic matter from a given volume in 1900 than it does in 1899. This comparison, however, is made between the river at the time of high floods in the second year and through the summer conditions in the first year. From the fact that these analyses which I last gave, made in 1900, were carried out in the spring of that year, when the waters in general were high, any comparison between the river at this time—the lower stretches of the river at this time with the lower stretches of the river in 1899. is impossible—any fair comparison is impossible. The Illinois River in the spring of 1900 in its lower stretches shows the condition of the ordinary western rivers at the same time, irrespective of the source of their contamination. We have here the large amounts of free and albuminoid ammonia, and high figures for oxygen consumption, which are found in the ordinary tributaries of the river. A comparison in this table

is important mainly as it shows the increased contamination at Peoria or Wesley." (4181-5.)

Tables were introduced in evidence on pages 4186 to 4208 inclusive, showing the results of examination made in the summer months of the year 1900. As to the results shown by these tables Professor Long testified:

"These tables considered in comparison with each other, and a consideration of the averages of the tables for the work of the summer of 1900, show in general, to begin with, a lower initial contamination of the water at Bridgeport than was the case in the examinations of the waters made in the previous year, 1899. The tables show further, as we proceed down the river and canal from Bridgeport to Lockport and Joliet, and down the Illinois River proper a gradual and continuous diminution in the factors indicating the organic contamination, and to an extent which is very much greater than can be accounted for in any way by the amount of dilution coming in from the tributaries. An examination of these tables shows first, in general, a marked reduction of organic matter as compared with the amounts present at the source of contamination—Bridgeport, in the main Drainage Canal. At the Narrows above Peoria, the factors indicating the extent of organic pollution as drawn from the results of the oxygen consumption test, and the free and albuminoid ammonia tests are not greater than those found from an examination of the ordinary tributaries—from the ordinary tributary waters of the Illinois in this state. We find also on further consideration of the table that after Peoria Narrows is passed and the next point is reached, a remarkable increase in the organic pollution again, as measured by the important factors already referred to, the oxygen consumption and free and albuminoid ammonia, this increase being in the free and albuminoid ammonia several hundred per cent. The figures for oxygen consumption increase are likewise very large. The increase, from

the known nature of the contaminating material entering the river at Wesley is largely nitrogenous, and hence the much greater increase apparent in the figures for free and albuminoid ammonia than that apparent in the figures for oxygen consumption. Below Peoria as we proceed down the river we observe a decrease again in these figures—a decrease in the oxygen consumption by the water, a decrease or disappearance of the free ammonia, and a very marked decrease in the albuminoid ammonia at Pekin. At the points below Pekin there is but little further decrease in the albuminoid ammonia for the reason that we have reached here a condition in the amount of albuminoid ammonia which is comparable with that found in the ordinary rivers of the state, beyond which the reduction does not commonly proceed to a great degree, for the reason that we have reached here the comparatively stable types of organic substances which are not much subject to reduction by the bacterial oxidizing agents. In the case of the free ammonia, however, as this substance does undergo change, we find a progressive improvement or disappearance by oxidation to the mouth of the river, the figure for free ammonia at Grafton being .07 parts per million. In considering the indications given by the figures for the oxygen consumption we have a similar condition. Below Pekin there is a general gradual decrease until Grafton is reached, where the figures for the oxygen consumption again have sunk to a point corresponding to those given by the waters of the tributaries entering the Illinois, and by waters of this type in general, which flow through soil containing a large amount of organic matter. These figures for oxygen consumption have reached a point which is not passed in the waters of this region when exposed to the contamination of ordinary organic substances of vegetable origin." (4208-10.)

* * * * *

"A consideration of all the tables presented and of the

charts drawn from them leads to this important and necessary conclusion: That in the flow of the sewage water from the pumps at Bridgeport through the Drainage Canal and subsequently into and through the river there is a very remarkable reduction or destruction of organic matter to Peoria; a great increase again between Peoria and Pekin, beyond which the reduction follows which continues to the mouth of the river, and at the mouth of the Illinois River as far as the organic content is concerned, the Illinois River is not more contaminated than are the ordinary tributaries and rivers of this region flowing through a soil which contains large organic matter, and finally, and the most important conclusion to be drawn from those tables and charts is that the main factor in contamination of the Illinois River is the addition of sewage, stock yards and distillery waste of the City of Peoria." (4226.)

This witness also testified that he made some chemical examination in 1901 and in the spring of 1902 of the Mississippi River above Grafton, the Illinois River above Grafton and the Missouri River above its mouth, and the tables showing the results of these examinations are introduced in evidence on pages 4230 to 4238 of the record.

Professor Long testified as follows as to the conclusions he drew from the results of this examination:

"From a consideration of these several tables, I draw the following general conclusions: That the organic condition of the Illinois River above Grafton is very much better than the organic condition of the Missouri River above its mouth. This is shown by several factors. By the factor measuring the oxygen absorption, which for the Illinois River is for the unfiltered water, 4.31 parts per million, and for the filtered water, 3.21 parts per million. For the Missouri River, for the unfiltered water, 10.28 parts per million, and for the filtered 3.17 parts per million. By the factor for the albuminoid ammonia,

as measuring the substances of comparatively complex composition to be yet decomposed, 0.413 parts per million in the Illinois, as against .6 parts per million in the Missouri. By the factor measuring the organic ammonia, as determined by the Kjeldahl process, which is .81 parts per million for the Illinois, as compared with 1.61 parts per million for the Missouri. As measured by the oxygen absorption, the Illinois River contains less organic matter above its mouth than does the Mississippi River. (4239.)

"As measured by the albuminoid ammonia, the Illinois River contains very nearly the amount of organic matter that is contained in the Mississippi River. As measured by the organic ammonia determined by the Kjeldahl process, the amount in the Illinois River is not greatly different from that in the Mississippi River. Considering the chemical reactions due to the living organic matter in the Illinois and the Missouri Rivers, it is evident that the condition of the Illinois is very greatly superior to that of the Missouri, throughout the whole period. This is especially shown by the chemical determinations made to indicate the presence of those living organisms which decompose protein matters, with the production of indol. The reactions for indol is found at the mouth of the Illinois River above Grafton very rarely, while in the Missouri River 600 feet above its mouth, this reaction is extremely common, showing a very much greater number of the living organisms capable of bringing about this peculiar chemical decomposition in the Missouri River than are found in the Illinois River. From the information obtained from the tests for the presence of those organisms, which have the power of breaking down carbo-hydrates, with the liberation of acid, which subsequently coagulates milk, it is likewise evident that the contamination in the Missouri River is very much greater than the contamination in the Illinois River through the same period. The number of acid forming organisms as disclosed by

the results of the tests being greater in the Missouri than in the Illinois. It also appears by a comparison of the tables in which a determination of the number of living organisms was made by the so-called colony count process, that the Missouri River shows a greater contamination than does the Illinois, through this same period. In its organic condition as indicated by these chemical tests which I have described as sometimes called bacterial, although they involve true chemical reactions, the Illinois River is as pure as the Mississippi at the point of junction of the Illinois with the Mississippi, and the Illinois river is very much purer than the Missouri at the point where the Missouri flows into the Mississippi. (4240.)

"When we turn to these results just given as applied to a comparison of the results for the fall of 1901, and when we turn to the results obtained in the spring of 1902, the same general conclusions follow. The indol reaction is more common in the Missouri River than it is in the Illinois. The purely chemical tests indicate the presence of a larger amount of organic matter in the Missouri River than is indicated in the Illinois. It is, beyond question, true, that at the period of this investigation the Illinois River at its mouth, was a much less contaminated stream than the Missouri River at its mouth. As disclosed by the experiments described, the Missouri River is far more contaminated organically than the Mississippi at the points at which the samples analyzed were taken. (4241.)

"From all the examinations I made of the Illinois River and its tributaries, it is my opinion that no part of the original organic matter leaving Chicago through the Sanitary Canal and finding its way into the Illinois River, can reach the mouth of the Illinois River, and much less the intake tower of the St. Louis waterworks. It is my belief that the sanitary condition of the water supply of St. Louis is not and cannot be injured by any pollution passing through the Drainage Canal from Chicago to the Illinois river and down.

"Q. Is the volume of water going down the Illinois River greater or less than it was before the opening of the Drainage Canal?

"A. The volume is now greater than it was before the opening of the Drainage Canal.

"Q. What has been the effect of this greater volume of water in disposing of the sewage of Chicago?

"A. As the sewage is disposed of in two general ways, practically, by dilution and by oxidation, or chemical destruction through bacterial means—inasmuch as the volume of water is greatly increased, the diminution of the sewage for a given volume, per cubic centimeter, for example, or per liter, is necessarily less, and inasmuch as at the same time with this new dilution there is no decrease enforced in the bacterial activity throughout the channel, so there can be no decrease in the purification from those causes. We have remaining, the diminution of organic matter by dilution, making the final effect better rather than a worse condition of the river. (4250.)

"The volume of water going down the Illinois River is now greater than it was before the opening of the Drainage Canal. I am acquainted with the Illinois River in flood time. The effect of very high water in the Illinois River is a complicated one. The floods carry into the river an immense amount of organic matter from all the tributaries and numerous living organisms or bacteria which are practically always associated with this organic matter. The floods in general, from the gathering up of this large amount of organic matter, have the effect of increasing the organic contamination irrespective of any original contamination which may have been present. A further effect of these floods, inasmuch as the banks of the Illinois River are very low, is to spread an enormous volume of water over an area of many hundreds of thousands of acres, providing for the sedimentation and oxidation to a marked degree, of the matters carried by the waters at these periods.

The conditions in the Illinois River because of the peculiar character of the banks, are unique in this respect. The overflow disposes in this manner of a vast amount of organic matter, which in a stream with high banks would have to be carried forward. The great overflow area provides numerout settling and purification basins in the Illinois River. Inasmuch as by far the largest volume of the water at flood time, leaves the natural channel of the Illinois River, and is distributed through a vast area of land, as a matter of necessity, any original sewage from Chicago or remnants of sewage carried by this water must be in a like manner, so distributed and delivered into a condition for purification by sedimentation or oxidation. (4251.)

"I am acquainted with the various lakes along the course of the Illinois River between Chicago and Grafton. Lake Joliet has the general effect of offering a large basin for oxidation and has the effect of holding up the water to some extent for that purpose. It is true for most of these lakes, in a far greater degree than Lake Joliet, which is in a measure hemmed in and limited in extent. These lakes, extensions and widenings of the Illinois River below Henry and particularly below Peoria and the region around Havana, north and south of Havana, and not in fact for the whole region practically between Havana and Beardstown, these widenings or lakes in the river provide very important agencies in the disposition of organic matter at flood time, and also to some extent at the time of low water. The Missouri River was not, at any period prior to the opening of the Drainage Canal a suitable river for household use. I made numerous analyses of the Mississippi River in years back, prior to the opening of the Drainage Canal.

"Because of the addition of a large volume of Lake Michigan water to the canal water flowing down the Illinois, and because further, the increase in the amount of pure water, is

very much in excess of the increase in the amount of sewage carried at the same time, the resultant effect is produced that the mouth of the Illinois River today, is in a far better sanitary condition than obtained before the Drainage Canal opened.

"Taking into consideration all the conditions which have been supposed and especially the condition of the increased pollution I am still of the opinion that the sanitary condition of the water of the Illinois River at its mouth has been improved instead of injured by the increased flow through the Drainage Canal. Since the opening of the canal, beyond all possible question the sanitary condition of the Illinois River at its mouth is far superior to the Missouri River at its mouth and not greatly different from the condition of the Mississippi River at a point where the Illinois and Mississippi Rivers unite.

"As I have stated in my previous testimony, I believe the effect of the Chicago sewage is completely lost before the mouth of the Illinois River is reached, and therefore cannot be a factor in determining any pollution in the Mississippi or Missouri Rivers. Assuming that the waters of the Illinois River in 1902 were emptied directly into the Missouri River at its mouth before the Missouri enters the Mississippi, the water of the Missouri would contaminate the water of the Illinois, the water of the Illinois being in a purer and better sanitary condition at that time than the water of the Mississippi." (4254-6.)

On cross-examination this witness testified as follows:

"The increased volume of flow in the river is a very important element. The increased flow in the Illinois River will put 20 times the volume of water at St. Louis than that which was discharged through the original Illinois and Michigan Canal; with a dilution of 20 times and no possible increase of contamination beyond perhaps 50 per cent., it is per-

fectly preposterous to think that there should be a larger amount of organic matter from Chicago in a given volume reaching the mouth of the Illinois under such conditions. In that answer I have taken into consideration the condition of the Illinois River as it existed prior to the opening of the canal and the condition of that river as it has existed since the opening of the canal. I have been familiar with the Illinois for 18 years. I have compared the volume of flow in the Illinois River before the canal was opened, with the volume after the canal was opened, the amount of sewage going into the canal, in the old Illinois and Michigan Canal, with the maximum amount which can go into the canal when the proper sewage connections are made in Chicago. (4349.)

"Frequently in the Illinois River, before the opening of the canal, it is a fact that the water was low. At times it was very low; but in those times, however, the Illinois River water received from a source outside of Chicago a very much greater portion of—or a somewhat greater portion of contamination than it does at the present time. The increase of water in the Illinois River has not carried any corresponding increase of contamination from Chicago at all. This increase of water has not been sufficient to impede in any material way, the rate of destruction of organic matter. As a matter of fact we find today at the mouth of the Illinois River in general a better organic condition than was found before the opening of the canal. (4350.)

"I will say, as determined by my investigation, that the condition of the Illinois River at its mouth after the opening of the Canal is very much better than it was before the opening of the Canal. It is evident from this fact that the conditions for the destruction, elimination, and reduction of organic matter must therefore be better now than they were in 1899.

"I suppose most of the water that passes through the

Canal and enters the Illinois River at its source, reaches the Mississippi River at the Chain of Rocks, subject of course to evaporation and absorption. When that water reaches there it is necessarily diluted. The only constituents of the sewage of Chicago which would remain with that water in its journey down the Illinois River would be the mineral or organic. They are the only ones of which we can say with certainty that they must remain largely, or in the main.

"From the study of all the results of the chemical analyses which I have made of the water from Chicago to Peoria, and through Peoria and to the mouth of the river, I see nothing in the condition at the mouth of the river which suggests at all that the condition to-day organically is any worse than that in the ordinary streams of the State, and any worse than that which might have existed in the upper Illinois River. In comparing the Illinois River at its mouth with the waters of the various tributaries through the season of 1899 and 1900, when such comparisons were made, I notice and have noticed, and have referred to the fact that the peculiar relation of the factors of albuminoid ammonia to oxygen consumption,—in other words, the ratio which the factors expressing the albuminoid ammonia bear to the factors expressing the oxygen consumption, are very similar, practically identical at the mouth of the Illinois River with what we observe in the examination of the tributaries. It is a peculiar and very interesting fact that for the tributaries the relation of the oxygen consumption is nearly a constant value which would be expressed, taking the average of all streams, by .07 about; we find by observing the same relation as I have before mentioned, several times practically the same figure at the mouth of the Illinois River, while the characteristic figures of waters with known animal pollution or containing essentially animal pollution, show a factor in mean about double this; so from these observations I am inclined to say that as far as the

organic pollution is concerned the Illinois River to-day as disclosed by the analyses I have made—and these are the only things on which I am at the present basing my opinion—is very similar, practically identical with the waters flowing through our State, and taking up a large amount of organic matter from the soil and decaying vegetation. (4389-90.)

"I insist emphatically that there is nothing to show that original contamination from the City of Chicago does reach the mouth of the Illinois River or the Chain of Rocks." (4393.)

Professor F. Robert Zeit made a bacterial examination of the same samples that Professor Long examined in the year 1900. The object of Professor Zeit's examination was the finding and the identification of pathogenic organisms and such other sewage and water bacteria that could be identified. (4415.) As a result of this examination he states:

"I found that there was a gradual decrease in the number as well as in the kind of pathogenic or disease producing bacteria in the water specimens submitted as we got further away from Chicago. Further, I found that bacteria that are generally known as sewage bacteria or saprophytic organisms gradually decrease as we approach Upper Peoria. The number as well as the kind of disease-producing bacteria, as well as the sewage bacteria, is continually decreasing to this point, and the absence of pathogenic effect in animals, I think, is also sufficient proof that the zone of bacterial self-purification, which every river has, which has become polluted, must be located somewhere above or near Upper Peoria. (4415-16.)

"I have gone all over the territory of the waters of the Chicago Drainage Canal and the Illinois River from Chicago to St. Louis and have seen the water and formed some opinions in regard to it. I have recently, about two weeks ago, something like that, gone over this whole region and observed the conditions that prevail in these streams.

"I think that in the Drainage Canal the growth and multiplication of immense numbers of saprophytes, due to the presence of a large quantity of organic material, is unfavorable to the life, the multiplication, or even the existence of disease-producing bacteria. I believe that in the Drainage Canal the conditions must be such that they are gradually wiped out, whereas in the Illinois River, the saprophytes are less numerous, and any disease-producing bacteria that would enter the Illinois River would be tremendously diluted, but they could probably exist no longer in the Illinois River than they could in the Drainage Canal. Any disease-producing bacteria that would get into the Illinois River could, on account of the absence of the decrease in the number of saprophytic bacteria, live no longer. The question could be answered by saying that in the Drainage Canal the existence or multiplication of pathogenic, disease-producing bacteria would be made impossible, and that they would disappear in such a sewage tank would depend also upon the resistance of the organism, but during the overgrowth of saprophytes. The time, of course, under the conditions of my laboratory experiments, I would judge that a week ought to be sufficient to wipe out all the cholera vibrio, staphlococci and typhoid bacillus." (4432-3.)

This witness also testified that he made some bacterial examinations of the waters at the mouth of the Illinois and Missouri Rivers and Mississippi River above Grafton in the year 1901-2.

After testifying as to the results obtained from these examinations the witness said:

"In my testimony to-day in reference to the examination of waters of the Illinois River, I stated that the self-purification of the Illinois River began at Morris and was practically completed between Henry and Upper Peoria.

"After a consideration of the results of the examinations

to which I have just testified, I do not see any reason for changing the opinion expressed, that bacterial purification has taken place in the Illinois River long before the water reaches Grafton. (4448-9.)

"Q. Assuming that the dejecta of typhoid fever patients in Chicago were deposited into the sewers of the city and were thence carried into the Chicago Drainage Canal and that the waters in that Canal contained immense numbers of saprophytes and ordinary water bacteria, to the number of 70,000 of them and frequently as many as four million per cubic centimeter, and assuming that it required at least 24 hours and as much as 48 hours for the water to pass from the Chicago sewers into the Chicago River and Drainage Canal and Beartrap Dam, and assuming that the flow in the Desplaines and Illinois Rivers is equal to forty miles in 24 hours. Under the conditions stated and from your own examinations of these waters and from your own experience as a bacteriologist, pathologist and biologist, would, in your opinion, such typhoid bacilli survive as far as Peoria? (4456.)

"A. In my opinion they would not, for the reason that the saprophytic bacteria increase at such a tremendous rate in the Drainage Canal as to actually overgrow and annihilate any pathogenic or disease producing bacteria.

"Q. Professor, knowing as you do the conditions that exist in the waters of the Chicago River, the Drainage Canal and the Illinois River and the Mississippi and Missouri Rivers at their confluence, and taking into consideration the enormous dilution which the sewage passing through the Drainage Canal receives from Lake Michigan and from other sources on its way to the chain of rocks in the Mississippi River, is it possible in your opinion for typhoid bacilli deposited into a sewer in Chicago which empties into the Chicago River to survive the passage and enter the intake of the St. Louis water works?

"A. In my opinion it is not possible that they can reach there. I have stated before that my opinion is based upon the fact that whenever conditions are made favorable for the rapid multiplication of saprophytic bacteria, pathogenic bacteria disappear, and it is my opinion further that the reason why reputable bacteriologists have been unable to find the typhoid bacillus in the polluted supply of streams or localities where a typhoid epidemic existed, was due to the same cause.

"Assuming that the dejecta of typhoid fever patients in Chicago were deposited in the sewers of the city and carried into the Drainage Canal and that the Canal contained immense numbers of saprophytes and ordinary water bacteria to the number of 70,000 and frequently as many as 4,000,000 per cubic centimeter, and assuming that it required at least 24 hours and as much as 48 hours for the water to pass from Chicago sewers into the Chicago River and Canal and Bear Trap Dam, and assuming that the flow in the Desplaines and Illinois Rivers is equal to 40 miles in 24 hours, in my opinion such typhoid bacilli would not survive for the reason that the saprophytic bacteria increase at such a tremendous rate in the Drainage Canal as to actually overgrow and annihilate any pathogenic or disease producing bacteria. Knowing the conditions that exist in the waters of the Chicago River, the Drainage Canal, the Illinois, Mississippi and Missouri Rivers at their confluence, and taking into consideration the enormous dilution which the sewage passing through the Drainage Canal receives from Lake Michigan and from other sources on its way to the Chain of Rocks, in my opinion it is not possible for typhoid bacilli deposited in a sewer in Chicago which empties into the Chicago River to reach the intake of the St. Louis water works. My opinion is based on the fact that whenever conditions are favorable for the rapid multiplication of saprophytic bacteria, pathogenic bacteria disappear. It is my opinion further that the reason why

reputable bacteriologists have been unable to find the typhoid bacillus in the polluted supply of streams or localities where a typhoid epidemic existed, was due to the same cause.

"In regard to the bacteriological flora of the three rivers during the examination of 1901-2, from the investigations made as a bacteriologist I would judge that the Missouri was more polluted than either the Mississippi or the Illinois during the periods of these examinations and that the Mississippi was more polluted than the Illinois at the same time. This investigation is entirely independent of any other data. It is simply to determine if the water of these three rivers, specimens of which were examined, is to be condemned bacteriologically, and which of the three is more dangerous than the other two, and I think, bacteriologically and qualitatively, that can be determined a great deal better in this way than by a great many of the methods that are employed sometimes as the more dependable methods by sanitarians. (4457-60.)

"I stated yesterday that the zone of bacterial purification of the waters of the Illinois as disclosed by my examinations of that river had been reached at Averyville, just above Peoria. The zone of bacterial purification is that part of a sewage polluted river where saprophytic organisms and pathogenic bacteria have disappeared and where the normal bacteriological flora of the river, before it received such pollution, is again established. In other words, where practically the same bacteria are found or exist that are found in the same river before it receives such pollution. The zone of bacterial purification varies in the different localities and in the different cities that empty their sewage into rivers, in its distance between very short distances, as short as nine miles, and longer distances, to the extent usually of forty miles. (4466.)

"As to the Illinois River, I think the zone of purification here ought to be even nearer to the City of Chicago than

what I have allowed, in fact, I think that the zone of purification is above Upper Peoria. I spoke of it simply there as being bacteriologically complete. I believe that the real zone of bacterial purification is complete very soon after leaving the Drainage Canal. (4469.)

"My opinion would be that pathogenic bacteria from the Chicago River would have died in the Drainage Canal before reaching the Illinois River, due to the great increase of saprophytic bacteria and the overgrowing of the pathogenic germs both in the sewers and the Drainage Canal. As to pathogenic bacteria it is my opinion there will be no source of danger to St. Louis or the inhabitants of Missouri from sewage deposited by the Drainage Canal from Chicago into the Illinois River at different seasons of the year and at different stages of water in the Illinois River, that is, if they use this water for drinking purposes. From 38 specimens of the Illinois River and 37 from the Mississippi River and 36 from the Missouri River made during the months of October, November and December, 1901, and February and March, 1902, I concluded that bacteriologically the Illinois River was less polluted than either the Mississippi or Missouri. During the period of these examinations, the effect of emptying the Illinois River into waters in which the Missouri River was a part would have only tended to make the Missouri less infectious, because the Illinois River was less infected than either the Mississippi or the Missouri was during those times. I would say that there would have been no source of danger to add the Illinois to the already severely polluted Mississippi or Missouri. (4472.)

"I do not believe that the Drainage Canal or the sewage entering the Drainage Canal can be of any danger due to pathogenic bacteria remaining in it, to St. Louis or Missouri, for the reasons already stated. My opinion being based mainly on the behavior of pathogenic bacteria in the presence of

saprophytes and my opinion also being based on the general knowledge the world over of the existence of a bacterial zone of purification in any river, and a continuous and permanent purification as the river flows along. As it flows along new pollution occurs and new bacterial purification zones form, which is my reason for feeling certain that no pathogenic bacteria entering the sewers of Chicago, or the Drainage Canal, will pass beyond Averyville, where bacterial purification was complete. This distance is much greater than that which is generally found the world over in every river. I would have liked of course very much to have more material, make more examinations, and to determine more positively the exact place of the bacterial purification, which I am quite certain is far above Peoria. I wanted to feel safe in saying that the absolute disposal of all pathogenic bacteria had been completed for the reason that even the saprophytic bacteria and the sewage bacteria have disappeared, and for the reason that here practically no bacterial pollution whatever of the river existed. Practically the same condition would apply to the germs of Asiatic cholera that apply in the case of typhoid bacillus." (4474-5.)

Upon cross-examination Professor Zeit testified:

"From my own investigation of the matter, I look upon the Drainage Canal as one big sewage tank, even as it is now, with an increased amount of water, and I hardly believe that very much will get out of the Drainage Canal in the way of pathogenic bacteria alive, because the conditions are certainly such as to show no lack there of organic material and no lack of saprophytic life. (4567.)

"If the Drainage Canal to-day is a septic tank, the effect of the discharge of 250,000 cubic feet of water per minute from Lake Michigan through that Canal, as much as I can see, is only that of dilution, and removing some of the objectionable features with regard to stench, it removes some of

the septic operations, but the septic operations and the disposal of pathogenic bacteria by rapid multiplication of saprophytes need not be carried to such an extent as to produce a nuisance by producing stench. There is no doubt a point between extreme dilution and stench where the same process will go on, the destruction of organic material, by saprophytes, and with it also the disposal of disease producing bacteria, and where at the same time, by dilution by lake water, the other objectionable features, such as stench can be removed. The septic operation might remain complete in the Drainage Canal even without destruction of the fauna and flora of the Illinois River, and the animal life, I will say, of the river. The addition of the 250,000 cubic feet of Lake Michigan water per minute in the Canal has, by dilution, reduced the septic operation, but not stopped it. The introduction of this 250,000 cubic feet of water per minute reduces the multiplication of the saprophytes and reduces the time limit for ultimate destruction of all organic material that is contained in the sewage of Chicago and discharged into the Canal, but at the same time it is not of such an effect as to allow pathogenic bacteria to remain, because there are no fish and no algae capable of living in the Drainage Canal. Therefore the action of saprophytic bacteria upon sewage and organic material in the Drainage Canal in spite of the great dilution that you speak of, has not been affected, so that I would say that the operation in the Drainage Canal, even with this large body of water that is turned in, is perfect as far as the multiplication of the saprophytes is concerned and its septic tank action." (4674.)

Adolph Gehrmann, physician and bacteriologist, states that he was the bacteriologist of the Health Department of the City of Chicago. He states that chemical and bacteriological examinations were made under his direction of the Illinois, Mississippi, Missouri and Desplaines Rivers, the tributaries

of the Illinois, etc. Tables showing result of the examinations made in 1899 are reproduced on pages 4770 to 4807, inclusive.

After taking into consideration the results of all examinations made, the opinion of this witness, as deduced from the above mentioned tables, is as follows:

"Q. Then if we assume that there is such a thing in the Illinois River as a zone of bacterial purification where in your opinion as a bacteriologist, is this zone to be found in the Illinois River?

"In reply to this question I can say that from the examination of the samples and the number of bacteria found, that there is a point at about Averyville where the condition as to the number of bacteria exists about equal to that of the tributaries of the river, and that the waters here show the least numbers of bacteria in the course of the river to the point at which they increase next below. I should therefore say that a degree of purification had taken place at about the location of Averyville in the river. My opinion would be from the bacteriological count that there was no particular difference in the bacterial purity of the waters in the Kankakee River and at Averyville and nothing that would indicate to us to what amount pollution had been applied between these points or near those points. The results of the examinations of the Illinois River water at Wesley City, and at Pekin showed very much the same condition. There is a wide variation between the counts made at different times, some being as high as two or three million, and others as low as 10,000. (4815.)

"In comparison, the examination of the waters of the Illinois River at Averyville shows in general a much smaller number of bacteria present, not in any instance having been over tens of thousands, and would indicate to me that the water of the Illinois River at Averyville is of greater bacterial

purity than the water of the Illinois River at Wesley City or at Pekin. From the difference in these results which is apparent, I attribute the increased bacterial count at Wesley City and Pekin, as compared with that at Averyville, to increased pollution of the river. I have seen that increased pollution coming from the City of Peoria and in that neighborhood. The results of the examination of the Illinois River water at Wesley City and Pekin as compared with those at Grafton, in the Illinois River, show that at Grafton there are from ten to twenty per cent. of the bacteria present, as shown in the samples from Wesley City and Pekin, and in some instances, one per cent. of the bacteria that are present at Pekin and Wesley City. I should conclude from this that the waters of the Illinois River at Grafton show a much greater bacterial purity than those at Wesley City and at Pekin. (4817.)

"Q. If you compared the waters of the Illinois River as disclosed by table 179 at Grafton, with the waters of the Illinois River at Averyville, as disclosed in table 172, what conclusion do you draw so far as these counts are concerned, as to the relative bacterial purity or impurity of the water?

"A. I should conclude that the bacterial purity of the water or its condition was about the same. I should conclude from the bacterial count made on samples of the water of the Illinois River at Wesley City, and Pekin and Grafton, that as far as the bacterial purity is concerned, the river had changed to the condition that we find it in from examination of the samples taken at Averyville, above the City of Peoria.

"Bacterial counts made of the samples of water taken from the Mississippi above the station at the Chain of Rocks, the pumping station of the St. Louis water works, all show practically the same bacterial counts, and I should conclude that the bacterial purity or impurity of the water at this point is about the same. There is no material difference in the bacterial counts from samples taken from the Mississippi River

400 yards from the Illinois shore at the Chain of Rocks as shown by table 186 and samples taken at the same place 400 feet from the Missouri shore, as shown by table 189. Examination of the results of samples of Mississippi River water taken at the Chain of Rocks, as shown in table 188, compared with the examination of samples of the Mississippi River water taken at Jefferson Barracks, 100 yards from the Missouri shore, shown in table 195, show no material differences as to the number of bacteria present, and I should conclude that the waters at these particular points show approximately the same bacterial purity or impurity." (4818-19.)

Professor Arthur W. Palmer is Professor of Chemistry in the University of Illinois. He made examination of the waters in question in this controversy and tables showing the results of his examination from May 23 to December 27, 1899, are reproduced on pages 4139 to 5026, inclusive, of the record. He also made an examination during the year 1900, the results of which are shown on tables reproduced on page 5050 of the record. As a result of the examination made in 1899 this witness states on record 5092:

"A consideration of the analyses of the individual samples given in tables 28 to 31 shows that the proportions of the nitrogenous organic matters never during the given period were so great in the Illinois River water as they were in the Missouri, and that the minimum proportion of these matters in the Mississippi and in the Missouri River water never reached quite the low point that they did in the water of the Illinois River at Grafton. The general conclusion from the consideration of these data, which, however, it must be remembered cover simply the period from the beginning of May, 1899, to December 31, 1899, is that the water discharged from the Illinois River is in these respects in purer condition than the water of the Mississippi River just above Grafton,

or the water of the Missouri River at Fort Bellefontaine, or West Alton, and that it is in most respects quite similar to the waters of the larger tributaries of the Illinois." (5092.)

Plates 9 and 10, introduced with the testimony of this witness, were made up from chemical data obtained from the examination of the waters in question. The witness states:

"Referring to plates IX and X, we may observe that in 1899 a considerable proportion of nitrogen as free ammonia was contained in the water of the Illinois and Michigan Canal and that although the proportion contained in the Desplaines River at Joliet was considerably diminished through mixing with the waters of the upper Desplaines River, yet considerable proportions of free ammonia were found in the river as far down as La Salle, but that the diminution still proceeded as we passed down the river until we find the minimum at Averyville. Below Averyville the free ammonia increased in proportion again, reaching the maximum at Pekin, diminishing then more rapidly and continuously until the mouth of the river at Grafton is reached. The curve for 1900 shows of course the effect of dilution with lake water in the Sanitary Canal, that is the proportions of nitrogen as free ammonia never were so great in the water flowing into the upper end of the canal and past the points between that and Grafton as they were in the preceding year in the Illinois and Michigan Canal and the Desplaines River and the Illinois River. Otherwise the curves show similar features, that is the very rapid diminution of free ammonia until we reach Averyville shows that the natural decomposition of the organic matters is taking place very vigorously in the upper reaches of the stream, but this action diminishes as we proceed down stream. The indication being that the diminution of the bacterial action is caused mainly by the exhaustion of the nutrients, that is, the supply of substances which are being converted by bacteria through ammonia into other innocuous forms of

matter and which may be regarded as the food supply of the bacteria, is more rapidly diminishing. It is notable that the proportion of free ammonia increases again below Averyville, but afterwards diminishes until we find at the mouth of the river considerably less than elsewhere along the course of the stream and less during the summer of 1900 than during the summer of 1899." (5127-8.)

Witness also states that he made an extensive examination of the waters in question in this case, beginning with the year 1897 and including the years 1898-9 and 1900 in connection with the examination made expressly for this case in the years 1900-1-2, and that the examination made from 1897 to 1900 was made in pursuance of an act of the General Assembly of Illinois authorizing the University of Illinois to establish a chemical and biological survey of the waters of the State in connection with said University.

The examinations conducted by this witness are related by him beginning with page 4905 to 5638, being over 600 printed pages of the record in this case.

Professor Palmer's examinations extended for over fifteen years and were very elaborate in their character. We respectfully invite the attention of the court to an inspection of the record, which will show the character of the examination made. The witness testifies on record 5638:

"Touching the questions at issue in this case, the real value of the evidence which I have introduced in this case in the way of analytical data lies in the comparison which it institutes between the period prior to the opening of the Chicago main drainage channel and the period subsequent to that opening. For the reason that the various determinations so far as they themselves were concerned, and including the collections of the samples, were made under precisely the same conditions throughout both periods, and that they afford data which are strictly comparable, and which show

the conditions prevailing in the waters of the streams in question before and after the great change which was coincident with and produced by the opening of the Chicago main drainage channel. I have lived upon the watershed of the Illinois River for about 36 years. During a portion of that time living on the banks of the Fox River, one of the chief tributaries of the upper Illinois, and I have been fairly familiar with the conditions prevailing upon the watershed of the Illinois River and with the conditions along the stream itself during the last ten years, and am familiar with the conditions prevailing along that stream and upon much of its watershed today.

"Taking into consideration my knowledge and information concerning the Illinois River, its tributaries, its watershed, and the conditions prevailing upon and along the same, and taking into consideration the chemical examinations that I have made of the waters of the stream and its various tributaries, both before and after the opening of the Chicago main drainage channel, it is my opinion that the effect of the greater discharge of water resulting from the operation of the Chicago main drainage channel, has greatly improved the condition of the water of the Illinois River all along its course, rendering its waters less offensive to the senses in the immediate neighborhood of the point of discharge of Chicago's sewage into the Desplaines and thence into the Illinois, and reducing the proportions of the organic matters contained in the waters of this stream at Averyville and at other points along its course, and reducing the proportions of nitrogen as free ammonia and as nitrates, and reducing also the quantities of nitrogen as ammonia and as nitrites contained in these waters, and in reducing not simply the proportions, but reducing also the actual quantities of the nitrogenous organic matters contained in the waters of this stream at various points, and particularly at Averyville, to all of which I have testified heretofore, in the evidence I have presented in this case; and with respect

to Kampsville I may refer to my testimony given above in this case, and state it as my opinion here, based upon the considerations enumerated above, that the condition of the water at Kampsville has been greatly improved co-incident with and as a consequence of the operation of the Chicago main drainage channel, in that my evidence shows a great reduction in both the proportions and the actual quantities of the most significant constituents of these waters as determined by the sanitary chemical analyses. And I base this opinion further upon the fact that since the opening of the Chicago main drainage channel, or sanitary canal, although the quantities or organic matters in the sewage now discharged into the Desplaines and thence into the Illinois River, are 30 per cent. greater than before that opening, the proportions of organic matters contained in the waters discharged by the Illinois River into the Mississippi are considerably smaller than they were prior to 1900; and that this decrease of the proportions is not a mere dilution is shown by the fact testified to by me, that the actual quantities of organic matters discharged are now less than they were formerly. I have visited the mouth of the Illinois River, the mouth of the Missouri River and the Chain of Rocks in the Mississippi River repeatedly and am somewhat familiar with the state of affairs there.

"From a consideration of my knowledge and information concerning these bodies of water, and a consideration of the results of investigations I have made of these waters, and the study of investigations made by others of these same waters, it is my opinion that neither the water of the Illinois River at its mouth, nor that of the Mississippi River just above the mouth of the Illinois River, nor that of the Missouri River just above its mouth, is suitable for domestic use; that is, particularly for drinking purposes without filtering, or without such treatment as shall render it sterile as by boiling or other means. From the knowledge and information which I possess

concerning the waters of the Illinois River and the watershed of that river, the Drainage Canal and the Desplaines River, and the conditions existing in and about them, and the results of the investigations which I have made of these waters before and after the opening of the Chicago main drainage channel and the knowledge I have of investigations of these same waters made by others before and after the opening of the Chicago main drainage channel, it is my opinion that the effect of the increased flow secured by the opening of the Chicago main drainage channel has been at times to increase the flow of water in the Mississippi River along the western borders of the State of Illinois and the eastern borders of the State of Missouri, and further it is my opinion that the increased flow secured by the opening of the Chicago main drainage channel containing as it does, increased quantities of organic matters derived from Chicago sewage, does not injuriously affect the waters of the Mississippi along the eastern borders of the State of Missouri so far as the use of such waters for domestic, agricultural and manufacturing purposes is concerned, for the reason that the effect of the increased flow secured by the opening of the Chicago main drainage channel, has been co-incident with or the cause of more complete destruction of the organic matters introduced into the upper Illinois River to such an extent that the waters discharged by the Illinois at its mouth contain less organic matters than they did prior to the opening of the Chicago main drainage channel, and further for the reason that it is my opinion that the organic matters contained in the Chicago sewage conveyed into the Illinois River by the Illinois and Michigan Canal and the Chicago main drainage channel, so far as the sanitary chemical analysis can determine, are destroyed completely or converted into mineral matters and vegetable matter, which as contained in such water are practically innocuous." (5638, *et seq.*)

Professor T. J. Burrill examined bacteriologically the samples collected for Professors Jordan and Palmer during the years 1899-1900-1. For the years 1899 and 1900 twenty-eight hundred samples were examined and the number of entire cultures made from these samples amounted to about seven thousand. (5716.) He testified as to the results of his examination as shown by the tables introduced in evidence and states:

"This indicates to me that the waters through this course of the stream, have in them great quantities of decomposable organic matter suitable for food for these organisms, and that the other conditions are such that the latter multiply enormously in these waters; but between Morris and Ottawa the indications are from these plates, that a great change takes place; that the numbers of bacteria are greatly decreased. The decrease is out of all proportion to the increase of water received by the stream during this time, or in other words, the amount of dilution that the stream has after passing Morris. This decrease in the number is maintained with some irregularity to Averyville, where the number found on an average, equals that of ordinary river water, not especially subject to contamination. This seems to be true in every case, as shown by these plates for the condition of things in the Illinois River at Averyville.

"This showing seems to prove that the pollution of the water at Bridgeport, and subsequently near the head waters, has practically disappeared at Averyville.

"The plates taken together show very conclusively great pollution of the stream below Averyville, but that the organic matter is largely absent in the course of the stream after it reaches Havana, and especially so at the mouth of the Illinois at Grafton.

"There is practically no difference so far as shown by these plates, in the waters of the Illinois River before they enter the

Mississippi River at Grafton, and of the Mississippi River above the mouth of the Illinois River at this place. There is, however, a continuous exhibit of a greater number of bacteria in the waters of the Missouri River at West Alton than there are in either the Illinois River or the Mississippi River at Grafton. (5748-9.)

"When, in the examination of water at different points in a river, I discover a material reduction in the number of micro-organisms I think I am entitled to infer that the matter suitable for food for these bacteria has disappeared, and since, as has just been said, sewage is the richest food commonly in such water, I may further infer that the sewage has disappeared."

(Plate XXIX and XXX being identifications of bacillus coli communis in the Illinois and Mississippi Rivers and tributary streams, are reproduced on page 5754. Witness reads from these plates and states that this indicates that the organism is most often present in the waters of the Missouri River; next in those of the Illinois at the mouth and somewhat less frequently in those of the Mississippi, if we take into consideration the whole time of the investigation.) (5756.)

"By reference to the graphical showing in this connection it will be seen that the less number of positive results through the whole course of the stream from Bridgeport to Mitchell (St. Louis Intake) was at Averyville, there being a slightly greater per centage of positive results at Grafton than at this last place. The greater number shown for the waters collected near Mitchell, seem to be due to the larger proportion or greater number in the waters of the Missouri River.

"In my opinion the very decided reduction of the number of the bacteria found in the course of the stream up to the time the waters reached Averyville, causing the waters at this place to assume the character of a normal river water, indicates that the contaminations from the sewage introduced

into the stream from Chicago have disappeared at this point, and I cannot otherwise than conclude that the evidence now presented shows that the water at the mouth of the Illinois River at Grafton is practically free from any such contaminations introduced at Chicago.

"I find also that the contamination as indicated in the water at the inlet tower at the Chain of Rocks, has a larger portion of its contamination from the water of the Missouri River rather than from the combined waters of the Illinois and the Mississippi at this point. I can say that the opening of the drainage canal has had no effect upon the waters of the Mississippi River one way or the other.

"I made bacterial examinations of the waters of the Illinois River, the Mississippi River and the Missouri River in the months of October, November and December, 1901.

"These examinations were conducted for an extension of the examinations made in the years 1899 and 1900 and for the same purposes so far as relates to the condition of the waters in the stream. I prepared tables which are intended to indicate the number of bacteria in a cubic centimeter, and the identifications of the bacillus coli communis in the weekly samples taken from the Illinois River at Averyville, at Pekin, at Grafton, and from the Mississippi River above the mouth of the Illinois at Grafton, and from the Chain of Rocks in the Mississippi River, and from the Missouri River at Fort Bellefontaine. (5769.)

"This series of investigations shows very closely just what was presented in the series for 1899 and 1900, already presented, and gives clear evidence that the water from the stream of Averyville is comparatively pure, or at least free from great numbers of micro-organisms, and also quite commonly free from the bacillus coli communis. The percentages of total tests which were positive in this examination proved to be 6.2. (5772.)

"Q. That 6.2 per cent. refers to the percentage of times that you found the bacillus coli communis?

"A. Yes, sir. If we compare this with the water taken from the Pekin station, we find a very great difference, and it shows local contamination, since there are an average of 299,000 bacteria to the cubic centimeter, and 7.6 per cent. of positive tests for the bacillus coli communis.

"This pollution at Pekin seems to have disappeared at the mouth of the Illinois River at Grafton, since the average number of colonies is 8,441, and the percentage of positive tests for bacillus coli communis is 10.7.

"If we compare the results from the waters of the Illinois River near its mouth, with that of the Mississippi River above the mouth of the Illinois, we find the result in regard to the number of colony counts slightly in favor of the Mississippi River as was found in the previous case, the average here being 5,407. This difference between 5,407 and 8,441, may or may not show a constant condition of things, as the difference is too small for this purpose, but the tests in regard to these two waters made for the determination of bacillus coli communis, favor somewhat the Illinois River water as against the Mississippi River water, since the percentage in the former is 10.7 and in the latter 11.5.

"At the Chain of Rocks, where four samples were each time taken across the stream, the indications are that the pollution increases from the Illinois shore to the Missouri shore, as this series of counts show, namely, for the Illinois shore 52,177, for the midstream, 43,185; for the intake tower 127,862 and for the Missouri shore 32,845. This last is the only count which does not support the statement just made.

"For the determination of bacillus coli communis in the same water we find beginning with the sample taken near the Illinois shore, 21.7 per cent.; from midstream 50 per cent.;

from the intake tower 36.3 per cent.; and from the Missouri shore 57 per cent.

"Comparing now these last result with those obtained from the waters of the Missouri River at Bellefontaine, or as it is sometimes called, West Alton, the indications are that this latter stream is considerably more contaminated, since the average number of bacteria per cubic centimeter is 127,353, and the percentage of positive tests for bacillus coli communis is 57.1.

"This means, so far as this evidence can be taken to mean anything, that the waters at the intake tower are largely derived from those of the Missouri River, and to present this a little more clearly, the results of the examinations of the water from the Missouri at Bellefontaine and of those at the intake tower may be placed together. From the former, that is the Missouri, the average number of bacteria per cubic centimeter is 127,353; at the intake tower the average is 127,862. The percentage of positive tests for bacillus coli communis from the Missouri River is 57.1 per cent., and the intake tower 36.3 per cent.

"The whole examination seems to indicate that the water which is comparatively pure at Averyville, becomes very greatly contaminated at Pekin, clears up again at Grafton, and at this point compares favorbly with the waters of the Mississippi River above the mouth of the Illinois, and very favorably with those of the Missouri at Bellefontaine.

"Q. What significance do you attach in running river water to the presence of bacillus coli communis?

"A. The presence of this organism means to me more than anything else, that the water is contaminated with sewage, and that this shows its bad quality for drinking purposes.

"I will say that since bacillus coli communis, and bacillus typhosus is mainly derived so far as they are found at all in

water, from the same source, that the very common presence of the former may be held to give some indication, though by no means a positive proof, of the presence of the latter.

"Q. Did you have any difficulty in determining the presence of the bacillus coli communis in your examination of the water?

"A. I cannot say that we did.

"Q. Professor, on day before yesterday, in your testimony in this case, you gave it as your opinion that the sewage from the City of Chicago had not produced any effect either one way or the other, in the waters of the Mississippi River, covering the months of October, November and December, 1901. Please state whether you still entertain that opinion after taking into consideration the tables which you have given in evidence this morning?

"A. I don't think there is anything shown by these later examinations to warrant any change in that opinion." (5774-5.)

Professor Jordan, a bacteriologist testified:

"I have made analyses of the water of the Illinois and Michigan Canal; of the Chicago Drainage Canal; of the Illinois River; of the Desplaines River; of the Kankakee River; Fox River; Big Vermilion River; Sangamon River; Mississippi and Missouri Rivers, and of Lake Michigan for the Sanitary District of Chicago.

"There are really three periods of time, one extending from April or May, 1899, to the end of the year; the second period extending from the first of January, 1900, to the end of June, 1900, and the third period from October, 1901, to about the first of January, 1902." (5807.)

(Witness states where samples were taken and the places where taken are indicated on the tables which were thereafter introduced in evidence.)

"This 1901 series as I understand it, was taken by agreement with the authorities of the State of Missouri at certain designated points. Those points were at Peoria from a short distance above and below the city; at Grafton at the mouth of the Illinois River, samples being taken from both the Illinois and the Mississippi at this point, and at the Chain of Rocks, the source of the water supply of St. Louis, where samples were taken across the stream as in the preceding examinations. Examinations were also made from the Missouri River at Fort Bellefontaine." (5809.)

The tables showing the result of the examination made by this witness are known as Jordan's tables Nos. 81 to 158 inclusive, and are reproduced in the record beginning at page 5818. This witness says:

"Table No. 89, reproduced on page 5834, contains the results of analyses of water from the Illinois River at Ottawa, Illinois, samples being taken from June 19th, to December 28th, 1899, before the opening of canal. In the flow from Morris to Ottawa a very considerable change takes place in the composition of the water. This is partly due to more thorough mixing, but in a large part due to changes in the constituents of the water. The albuminoid ammonia and free ammonia, the oxygen consumed the number of bacteria are all lower than at Morris, indicating that a really considerable purification of the water has taken place during its passage from Morris to Ottawa. (5835.)

"Table 92, reproduced on page 5839 contains the analyses of samples from the Illinois River at La Salle. The samples were taken above the town and were taken between May 24th and December 26th, 1899.

"The various determinations show that considerable purification has taken place in the Illinois River during the flow from Ottawa to this point, a distance of 22 miles. (5841.)

"Table 94, reproduced on page 5844, contains the analyses

of samples of water from the Illinois River at Averyville, Illinois, the samples being taken on various dates between May 30th and December 26th, 1899.

"Between Henry and Averyville there is practically no addition of impurity and little dilution, so that the changes occurring in this flow of 36 miles are due to oxidation and other processes. The point where the samples were taken is at the place known as the Narrows, near the Peoria waterworks above the City of Peoria, and before any pollution from the city enters the river.

"The large amount of nitrogen in the form of nitrates at this point shows that a very considerable amount of oxidation of the organic matter has taken place. The small number of bacteria shows that the stream which was originally laden with the bacteria of the Chicago sewage derived from the Illinois and Michigan Canal has practically freed itself from these bacteria in this flow of about 160 miles.

"Table 95, reproduced on page 5846, contains analyses of samples of water taken from the Illinois River a short distance below Peoria near the place known as Wesley City. The samples of water were taken on different dates from May 29th, to December 28th, 1899. A large part of the sewage of Peoria, a city with a population of about 60,000, enters the Illinois River between Averyville and Wesley City. In addition to the house sewage the discharges from extensive stock yards, the slop from distilleries and other refuse enter the river above this point of collection. The large number of bacteria in the water indicates the organic character of a large part of this pollution and shows the extent as well as the nature of the defilement. (5847.)

"Table 96, reproduced on page 5848, contains analyses of samples of water taken from the Illinois River at Pekin between May 24th and December 28th, 1899. The mixing of the Peoria sewage and refuse with the river water has become

more nearly complete by the time this point is reached, and in addition to the sewage of Pekin, a city with a population I believe of about 8,000, has entered the river, together with considerable distillery refuse. The sample was taken far enough below Pekin to get the effect of all this pollution, and so far as practicable to show the mixing of the pollution, although here, as at Wesley City, the amount of pollution shown by the water in the middle of the stream was not the same at all times.

"Table 97, reproduced on page 5850, contains analyses of samples of water from the Illinois River at Havana, Illinois, the samples being taken between May 30th and December 20th, 1899. A considerable degree of purification takes place between Pekin and Havana, as shown by the different determinations in this table. (5849-51.)

"Table 100 contains analyses of samples of water taken from the Illinois River at Kampsville, Illinois, between May 31st and December 20th, 1899. Between Beardstown and Kampsville only a very small amount of polluting material enters the Illinois River. In fact, from Beardstown to the mouth of the river at Grafton, the polluting matters entering the river are relatively insignificant. Some dilution, however, occurs from small tributary streams. The small number of bacteria found on many occasions in the water of the Illinois River at Kampsville, together with the amount of nitrates in the water, shows that the river at this point has practically regained the condition that it possessed at Averyville, above Peoria. (5857.)

"Table 101, reproduced on page 5858, contains the analyses of samples of water taken from the Illinois River at its mouth at Grafton, the samples being taken between May 10th and December 27th, 1899. These samples were taken at a point in the Illinois River where no mixing with Mississippi River water was possible. The condition of the Illinois River at this point compares very favorably chemically and bacterially

with the water of the Illinois River at Averyville and with the tributary streams entering the Illinois. (5859.)

"From a sanitary standpoint, the water of the Mississippi River above Grafton, does not differ materially so far as can be determined by chemical and bacterial examinations, from the water of the Illinois River at its mouth.

"Table 127, reproduced on page 5899, contains the analyses of samples of water taken from the Illinois River at Morris between January 5th and June 26th, 1900. (The Canal was opened January 17, 1900.) During the month of January the conditions were not dissimilar to those prevailing during 1899, but the analyses for subsequent days show in several ways the effect of the dilution of the Chicago sewage in the Chicago Drainage Canal.

"The smaller amount of chlorine particularly is evidence of this increased dilution and on several occasions notably in the month of May, the number of bacteria in the Illinois River at this point was lower to a striking degree, than at any time in the preceding period. (5900.)

"Table 129, reproduced on page 5903, contains analyses of samples of water from the Illinois River at Ottawa between January 4th and June 25th, 1900. The various determinations chemical and bacterial, especially those showing the amount of albuminoid ammonia, free ammonia and nitrates and the number of bacteria per cubic centimeter, indicate that a considerable change in the direction of purification has taken place between Morris and Ottawa as in 1899. (5904.)

"Table 133, reproduced on page 5911, contains analyses of samples of water from the Illinois River at Henry between January 3rd and June 25th, 1900. Here again is shown the increase in the number of bacteria in the river water during the late winter and early spring. This has already been shown to be a common phenomenon in river water and occurs in the tributaries of the Illinois as well as in the Illinois itself.

The diminished chlorine in the latter part of this period shows the effect of the dilution due to the opening of the Chicago Drainage Canal. (5912.)

"Table 134, reproduced on page 5913, contains analyses of samples of water in the Illinois River at Averyville from January 2nd to June 26th, 1900. Both the effects of purification and dilution are shown in this table, especially during the latter part of the period when the effect of the condition of early spring had disappeared. (5914.)

"Table 135, reproduced on page 5915, contains analyses of samples of water in the Illinois River at Wesley City. The smaller number of bacteria during this period as compared with the 1899 period shows that the pollution entering the Illinois River at Peoria, has been crowded in part towards the western bank and does not make its presence so evident in mid-stream as was the case during 1899. (5916.)

"Table 136, reproduced on page 5917, contains analyses of samples of water taken from the Illinois River at Pekin from January 11th, 1900, to June 27th, 1900.

"The effect of pollution here in mid-stream sample is more manifest than in the samples from Wesley City owing possibly to a more thorough mixing at this point. (5918.)

"Table 137, reproduced on page 5919, contains analyses of samples of water taken from the Illinois River at Havana, between January 11th and June 27th, 1900. The purification in the river as shown by the amount of nitrates and the number of bacteria is manifest here as well as in the 1899 period. (5920.)

"Table 138, reproduced on page 5921, contains the analyses of samples of water from the Sangamon River at Chandlerville, from January 3rd and June 27, 1900. The usual spring increase in the number of bacteria is manifest at this point as in the other tributaries of the Illinois and in the Illinois River itself. (5922.)

"Table 139, reproduced on page 5923, contains analyses of samples of water from the Illinois River at Beardstown from January 4th to June 28th, 1900. Taking into consideration the greater dilution of the water at this point, the analytical data are not materially different from those covering the 1899 period.

"Table 140, reproduced on page 5925, contains analyses of samples of water taken from the Illinois River at Kampsville from January 3rd to June 27th, 1900. The usual spring rise in the number of bacteria, the amount of free ammonia and albuminoid ammonia and so on, is manifest here as elsewhere, but during the latter part of the period the condition of the water both chemically and bacterially compares very favorably with that in the 1899 period.

"The number of bacteria averages less at Kampsville than at Averyville. The amount of free ammonia is on the whole lower. The albuminoid is very similar.

"The nitrates are on the whole lower at Kampsville than at Averyville during this period. (5926.)

"The nitrates are also lower, and the oxygen consumed on the whole does not differ materially.

"Table 141, reproduced on page 5927, contains analyses of samples of water from the Illinois River at Grafton, taken between January 4th and June 29th, 1900.

"A very considerable degree of purification is shown chemically, and in the latter part of the period bacterially also, as compared with the collecting stations in the upper stretches of the river. The increased volume of water in the Illinois River, especially in the months of March and April, is reflected in the lower chlorine content during this period. (5928.)

"From an examination and consideration of the tables of separate analyses and the tables of averages for this period,

the period of 1899, it appears that the water in the Illinois and Michigan Canal at Bridgeport and Lockport, as well as the water of the Desplaines River at Joliet and of the Illinois River at Morris, contained throughout this period a large amount of nitrogenous organic matter in the early stages of decomposition. It appears also from the large amount of chlorine present in these waters that the initial pollution of the Illinois River reached a considerable height during this period. The large number of bacteria present in these waters shows that the substances capable of serving as food for these organisms were present in great abundance. (5960.)

"The tables and averages also show that by the time the Illinois River reaches Ottawa, being somewhat diluted in its course by the purer waters of the Kankakee, mingling with which is incompete at Morris, a very great change has taken place in the composition of the river water, a change which is manifested especially by the diminution in the amount of albuminoid ammonia by the increase in the amount of nitrites and nitrates, and particularly by an enormous and significant diminution in the bacterial content.

"The oxidation of the organic matter continues with the passage of the water down stream and by the time the flow reaches Averyville the amount of free ammonia is greatly diminished as compared with the amount at Ottawa. The amount of albuminoid ammonia is diminished. The amount of nitrates has greatly increased, while the bacteria which were present in such enormous numbers in the waters of the upper Illinois have now sunk to a point where they can be compared with the number present in ordinary surface waters in the United States and with the number present in the tributaries of the Illinois during this period.

"Below Averyville the Illinois River receives a large influx of polluting material from Peoria with its stock yards and distilleries, which is evidenced by the increase in some

of the significant constituents in the river water, notably in the free ammonia and the albuminoid ammonia and in the number of bacteria.

"At Pekin some additional sewage is received and the mingling of the Peoria sewage with the Illinois River water has become more perfect. From Pekin to the mouth of the river, the purification follows a generally progressive course, until by the time the mouth of the river is reached at Grafton, the amount of free and albuminoid ammonia, the oxygen consumed by the carbonaceous matter and the number of bacteria are again low, while the relatively large amount of nitrates bears witness to the practically complete oxidation of the enormous amount of organic matter with which the sewage was laden at Peoria, as well as that with which it originally set forth at Lockport. The conditions in the Illinois River during the larger part of the period covered by these investigations are shown by analyses of samples collected at the same points and under the same conditions as in 1899, the whole series of analyses from May, 1899, to the end of June, 1900, forming one continuous period. (5963.)

"From April to June, 1900, analyses were made of the water from the Chicago Drainage Canal at Kedzie street and at Lockport. These analyses show that as compared with the condition of the water in the Chicago River considerable dilution has taken place as witnessed particularly by the chlorine determination, as well as by similar changes in the other constituents of the sewage.

"A mingling of the waters coming from the Chicago Drainage Canal at Lockport and from the Illinois and Michigan Canal at Lockport, with the waters of the Desplaines River which is subsequently joined by the Kankakee, took place during this period. The first admixture of the waters of the Drainage Canal took place on the 17th of January, 1900, after the canal had been filled and the gates finally opened.

"Examination of the separate analyses of the samples of water from the Illinois River at Morris and also of the averages of these analyses, shows that the water of the river at this point was charged with organic matter; that it contained a large amount of nitrogen in the form of albuminoid and of free ammonia; that the amount of oxygen consumed was high, and that the number of bacteria was still large.

"The samples of water taken from the Illinois River at Ottawa during this same period showed that considerable purification took place between Morris and Ottawa, the amount of free ammonia and of albuminoid ammonia and of oxygen consumed, being diminished, and the number of bacteria being little more than one-fourth the number in the Illinois River at Morris during this period. (5964.)

"By the time Averyville is reached the process of purification had proceeded still farther, both free and albuminoid ammonia being notably lower than at Ottawa.

"At this station also the amount of nitrate was high, showing that considerable nitrification had taken place in the flow from the Drainage Canal to this point. The number of bacteria was not half as great as in the Illinois River at Ottawa during the same period.

"A further addition of polluting water took place at Peoria and Pekin, with the result that in the lower half of the river the process of purification had again to be completed. How complete this purification was may be seen from the determinations at Grafton for this period, the amount of free and albuminoid ammonia in the water and the amount of nitrates indicating that this purification followed a parallel course to the purification in the upper half of the river.

"The second period, the conditions in which have been just described, has been arbitrarily separated from the first period, namely, that for the months May to December, 1899, but the analyses show plainly that the essential course of events

in the water of the Illinois River is the same, whether a period of two months, or five months or fourteen months, be considered.

"In all cases the same phenomenon is noticed. The water at the outset, highly charged with putrescible organic matter and laden with sewage material, regains in the course of about 130 miles flow the condition usually existing in surface waters in this country.

"The self-purification of the Illinois River during the period covered by these analyses, extending from May, 1899, to the end of June, 1900, is notable in character and extent, both at high water and at low water, both at low temperatures and high temperatures, and shows convincingly that under the *conditions prevailing in the Illinois valley during the period studied, the self-purification of streams is not an interesting biological myth, but an actual and definite occurrence.* (5965.)

(Witness gives reasons for the following statement:)

"From a comparison of the analytical data therefore, at this point, it is evident that the separation of the two periods on the basis of calendar years, is from the point of view of sanitary water analysis, an arbitrary one, and does not bear any definite relation to any meteorological or biological conditions.

"Throughout the period covered by this investigation, namely, from May, 1899, to the end of June, 1900, the water of the Illinois River at Pekin was usually in a more highly polluted condition chemically and bacterially, than the water of the Illinois River at Averyville. The large amount of sewage and refuse that enters the Illinois River at Peoria and at Pekin offers a sufficient explanation in my opinion for the increased pollution of the Illinois River at this point as compared with the condition of the river above Peoria, at Averyville, before this pollution enters. It is a somewhat difficult question to answer as to how far down the river from

Peoria the pollution which the Illinois River takes on at Peoria, disappears, because the conditions undoubtedly vary at different times of the year and with different rates of flow. * * * However, the water of the Illinois River at Grafton, is usually in a condition very similar to that obtaining at Averyville. Peoria is about 124 miles from Kampsville and Averyville is about 130 miles from Lockport. During this entire period my chemical and bacterial examinations do not disclose the presence at Kampsville of the sewage from Chicago whether from the Illinois and Michigan Canal for the first part of this period or from the Chicago main drainage canal for the second, so far as the number of bacteria in the water is concerned, nor do they, so far as the various chemical determinations of albuminoid ammonia, oxygen consumed, nitrites and nitrates are concerned. The large amount of chlorine that enters the Desplaines River (from the Drainage Canal) along with the Chicago sewage, is, however, permanent, and not being liable to destruction by various influences, as is the case with the nitrogenous organic matter and the bacteria, that are added in the Chicago sewage, the chlorine manifest itself at Kampsville and Grafton, and even beyond, into the Mississippi River. (5968-9.)

"The diagram reproduced on page 5979, designated, 'Number of bacteria per cubic centimeter in the Illinois River, Edwin O. Jordan, is a graphic representation of the average numbers of bacteria for May and June, 1899, and May and June, 1900, starting at Lockport with high initial numbers in both cases.

"The number of bacteria drops to a relatively low point in the neighborhood of Ottawa, continuing low to Averyville, below that point, showing a very notable increase, especially during the first period, apparently due to the pollution of Peoria. As with the initial pollution the numbers of bacteria introduced at Peoria diminish, and for the last stretch of 120

miles the numbers of bacteria are very similar to those found at Henry and Averyville above Peoria." (5980.)

This witness also testifies that he made an hourly examination of the waters of the Illinois River for three days, the averages being shown in the following tables taken from page 5988 of the record:

	Distance from Morris.	No. Colonies per c. c. Right Bank.	Center.	Left Bank.	No. of Hourly Analyses.
Upper Station (Morris)	.....	261,000	204,000	29,000	3
Middle Station (Seneca)	12 miles. 24 hours.	100,000	49,000	35,000	2
Lower Station (Ottawa)	24 miles. 48 hours.	11,500	10,700	13,500	2

"During this flow of 24 miles therefore, the Illinois River became nearly free from the great mass of sewage bacteria with which it was originally laden. In fact the bacterial content of the Illinois at Ottawa on this date was not greatly in excess of that of the local tributary streams."

The court will note that in the middle of the stream the number of bacteria at Morris were 204,000, which was reduced to 49,000 at Seneca and 10,700 at Ottawa. A chemical examination was also made of the waters collected for this experiment with the results shown on page 5988 of the record. In regard to this examination the witness states:

"In connection with this series of bacterial determinations may be given the averages of the regular chemical determinations made at the laboratory in Chicago during the period between October 23d and November 20, 1899. These determinations, which follow, show that a considerable degree of nitrification takes place in the river between these two points, as witnessed by the increase in the amount of nitrites and nitrates, the diminution in free and especially in the albuminoid amonia."

Other experiments of a like character were made and the witness testifies as follows in relation to same:

"I see no escape from the conclusion that in this flow of approximately 25 miles, the Illinois River which at Morris con-

tained a large number of bacteria in all probability derived more or less directly from the sewers of Chicago freed itself from these bacteria to a remarkable and impressive degree in a short distance and, in a relatively short space of time. The probable reason for the high mortality among bacteria in this particular stretch of the river will be discussed in another connection." (5991.)

The witness further states on record page 5993:

"These observations upon the bacterial content of the Illinois River between Morris and Ottawa indicate in my judgment that a very large proportion of the bacteria entering the Desplaines River from the Illinois and Michigan Canal and from the Chicago Drainage Canal do not survive to reach Ottawa. From a sanitary point of view this observation would seem to be of importance in that it renders less probable the passage of disease germs down the river, as far as this point. Since these sewage bacteria disappear in such numbers, it is my opinion, fair to assume that the various non-spore forming pathogenic bacteria entering the Chicago sewage, die out at least in the same proportion.

"In giving the last opinion I am of course obliged to take into consideration all the knowledge that I possess on the life of pathogenic germs and their relation to sewage bacteria. I regard however, these observations upon the bacterial content of one and the same body of water as reinforcing in a remarkable manner all that I have been able to learn in other ways regarding the life of bacteria introduced into water with sewage." (5994.)

This witness made what are called "coli determinations" about which he testifies as follows:

"So far as I have been able to discover, it is at the present time, the prevailing opinion among those bacteriologists who deal with sanitary water analysis that the test for the coli

bacillus properly applied and interrupted, furnishes one of the most satisfactory clews to the sanitary condition of a water.

"In this connection it should be emphasized that it is not so much the presence or absence of bacillus coli communis in a large quantity of water that is significant as it is the relative abundance of this micro-organism.

"The relatively large number of colon bacteria present in the Illinois River at Morris as shown by Table IV has been greatly diminished between Morris and Averyville, so that while at Morris the colon bacillus was found almost invariably in .1 of a cubic centimeter of water, at Averyville it was but rarely present in this amount of water, and occasionaly absent even in one cubic centimeter of water. This group of organisms appears to have suffered a great mortality in the water between Morris and Averyville. (6022.)

"(Table XI, Illinois river at Wesley City.)

"The increased pollution of the river at this point is shown by the swollen number of colon bacilli, which were found quite often in .1 of a cubic centimeter of water. Table XII, Illinois River at Havana. The colon bacillus was commonly present in one cubic centimeter of water.

"(Table XIII, Sangamon River at Chandlerville.)

"As before stated, the Sangamon River receives above Chandlerville, the sewage of a very considerable urban population, and this condition is reflected in the relatively high number of colon bacilli, which during the period covered by these determinations, range much higher than the number found in the water of the Illinois River at Averyville, as evidenced especially by the determinations made of .1 cubic centimeter samples. The colon bacillus was even found occasionally in .01 of a cubic centimeter of water taken from the Sangamon River at this point. (6026.)

"(Table XIV, Illinois River at Grafton.)

"The colon bacillus was present in .1 of a cubic centimeter samples in about the same proportion as at Averyville, and was present in the majority of one cubic centimeter samples, as is usually found to be the case with unprotected surface waters receiving at more or less frequent intervals the drainage of urban and rural communities." (6028.)

After giving some of his results at points where examinations were made witness states:

"These summaries show that the colon determinations coincide with the results of the routine chemical and bacterial examinations already referred to.

"The processes of oxidation of the organic matter, the death of the mass of sewage bacteria and the mortality among the specially significant group of colon organisms appear to run a closely parallel course, and the inference as to the purification of the stream drawn from the chemical analyses and from the count of bacterial colonies, is further emphasized by the mortality shown to occur in this significant class of sewage bacilli.

"It appears therefore from these tables, that if the opinion that I have expressed regarding the sanitary significance of the colon bacillus in water is correct, the water of the Illinois River at Averyville and Grafton was not materially different from what it would have been if the tributaries of the Illinois, exclusive of the Desplaines River and its sewage content (the sewage coming through the Drainage Canal), had alone fed the basins of this stream. The colon content of such a stream at Averyville and at Grafton would have been substantially what it is at present.

"As stated in my testimony of yesterday, my experience leads me to adopt the view that the relative abundance of the colon bacillus in water affords the most satisfactory single analytical indication that sanitary science at present possesses as to the sanitary quality of a natural water.

"Basing my opinion upon this I may say that I regard the relative abundance of colon bacilli in the water of the Illinois River at various points, and in the various tributary streams as furnishing a highly important clew to the freshness of the pollution entering, and the amount of real purification undergone by each stream. The successive and striking diminution in the number of colon bacilli at various points along the Illinois River from Lockport to Averyville, is proof in my judgment of the occurrence of a process of genuine self-purification. (6040.)

"I regard these determinations as forming a connected and correlated whole, mutually sustaining one another, and all pointing in my judgment, to but one interpretation. The oxidation of the organic matter that was introduced in enormous quantities at Lockport, the more or less complete destruction of sewage bacteria also introduced at this point, and especially the high mortality among the colon bacteria occurring in the upper stretches of the river, all appear to me to indicate that infectious matters that might have been introduced into the sewage of Chicago and found their way into the Drainage Canal during this period from May, 1899, to the end of June, 1900, did not make their way down river so far as Averyville. So far as my interpretation of the results of the chemical analyses, the bacterial counts and the colon determinations is concerned, I have no hesitation in expressing as my opinion that the water of the Illinois River at its mouth is no more liable to convey disease or to produce injurious consequences of any kind than the waters of the Mississippi River at this point, or the water of the Missouri River at West Alton. In expressing this opinion I am taking into consideration all the knowledge that I have acquired by personal experience and all the information that I have obtained regarding the chemical and bacterial content of these waters during the period under consideration.

"I made a survey of the waters of the Illinois, the Mississippi and the Missouri Rivers in 1901. So far as I understand these circumstances, an agreement was reached between the authorities of the State of Missouri and the State of Illinois, for conducting a joint investigation of the water of the rivers named, at certain points. The aim of this joint examination was, as I understand it, to secure that the samples should be taken at specified places, at specified times, and under uniform conditions." (6041.)

After considering all these examinations the witness states:

"In other words, so far as any conclusion as to the sanitary character of these waters can be drawn from the colon determinations—and I have already indicated that in my opinion and in that of sanitary experts generally, the colon test is the most delicate and satisfactory clue that we have to the sanitary condition of the water—the water of the Mississippi River above Grafton during this period was, if anything, of a less wholesome character than the water of the Illinois River above Grafton.

"Comparing further the colon content of the Missouri River water above Bellefontaine during this period it is shown that 19 per cent of the .01 cc. samples were positive as compared with 5 per cent. in the Illinois River at Grafton, and that 50 per cent. of the .1 cc. samples were positive as compared with 13 per cent. in the Illinois River at Grafton and that 79 per cent. of the 1. cc. samples were positive as compared with 30 per cent. in the Illinois River above Grafton.

"Comparing the percentages of positive results obtained in the examination of 1. cc. of water in cross section at Chain of Rocks it appears that there was a smaller percentage of colon bacteria in the Mississippi River on the Illinois shore and in mid stream than at the intake tower and on the Missouri shore. This confirms the difference already noted between the colon content of the Illinois River and the Mississippi River

at Grafton and that of the Missouri River at Bellefontaine. The higher colon content of the Missouri River betrayed itself in the larger number of colon bacilli found in the Mississippi River at the intake tower and near the Missouri shore at the Chain of Rocks.

"The sanitary significance which I attach to these findings is based on what I have been able to learn by my own observation and experiments regarding the significance and relative abundance of the colon bacillus in waters of various kinds as well as that derived from an examination of the available literature on the subject and the opinions of various sanitary experts already referred to in my testimony. It may be summed up by the statement that the water from the Missouri River during this period was distinctly more dangerous and unwholesome than the water of either the Illinois or the Mississippi River at Grafton, and further that the difference between the Illinois River above its mouth and the Mississippi River above Grafton while not great shows that on the whole the Illinois River was in a less highly polluted condition than the Mississippi.

"Those examinations were made in pursuance of an agreement mutually entered into between the representatives of the complainant and the defendant." (6122-3.)

Photographs of fermentation tubes are reproduced in the record and Professor Jordan testifies in regard to these as follows:

"Q. What do the photographs show, professor, as to the mixing of the waters at this point of the three rivers?

"A. They show that as far as the bacterial content is concerned the water flowing along the Missouri shore and by the intake tower was derived in large part if not wholly from the Missouri River while the water derived from the Illinois River clings to the Illinois shore and mixes little, if any, with the water of the Missouri.

"The character of these waters during this period as shown by the colon examinations and as set forth in the tables and illustrated by the photographs is quite different. The colon content of the Missouri River is markedly higher than that of either the Illinois or the Mississippi River at Grafton, and from this I infer that during this period the Missouri River was more highly charged with dangerous bacteria and was distinctly less safe than the waters of the Illinois River.

Under these conditions the effect of any mixture of the Illinois River water with the Missouri River water at the intake tower of the St. Louis waterworks would therefore tend to diminish the colon content of the water at that point, thereby rendering it less dangerous for the human use. Such mixing of the Illinois and Missouri waters as took place would hence improve the conditions existing during this period in the Mississippi River at the intake tower.

"Throughout this period, in the latter part of 1901, the water was low in the three rivers, the Illinois, the Mississippi and the Missouri." (6132.)

The witness further states:

"It is my judgment that the analyses made concurrently by Professors Palmer, Long, Zeit, Gehrmann and Burrill, no such extensive and exhaustive study of river water, in connection with the problem of self-purification of streams, has ever been made anywhere in the world as that carried out during this period. From my survey of the Missouri and Illinois Rivers, as evidenced by the various analyses heretofore testified to in this case, prior to the 17th of January, 1900, the condition of the Missouri River as compared with that of the Illinois above Grafton was less satisfactory from a sanitary point of view and was distinctly inferior to the Illinois River at Averyville.

"The relative character of the two rivers was not materially different from the 17th of January, 1900, to the first of July,

1900. That is to say, the Missouri River water was more objectionable from a sanitary standpoint than the water of the Illinois River at its mouth or at Averyville. (6138.)

"During the period October-December, 1901, when daily examinations were made and a large number of results obtained, the sanitary quality of the Missouri River water was, in my opinion, distinctly inferior to the Illinois River water at its mouth and at Averyville, as shown especially by the colon determinations.

"Taking into consideration all the analytical data that I have obtained throughout the seventeen months covered by the investigations, I conclude that one of the most remarkable facts, if not the most remarkable, is the entire concurrence of the results derived from the chemical and the various bacterial determinations. The amount and rate of nitrification in the water of the Illinois River at various points along its course, as shown by the tables of chemical analyses, are in the line with what the experience of water analysts has shown to accompany a real purification. The large amount of organic matter present in the upper stretches of the Illinois River is oxidized during its passage down stream, and before Averyville is reached the nitrification of this organic matter has progressed practically to completion.

"On the bacterial side, the evidence is wholly confirmatory of this improvement in the quality of the Illinois River water. The enormous number of bacteria poured into the Illinois River in its upper stretches, as shown by the number of bacteria present in the Illinois River at Lockport and Joliet, is greatly diminished in a flow of less than one hundred miles. Under certain conditions even, and at certain periods of the year, the Illinois River becomes nearly free from the great mass of sewage bacteria with which it was originally laden in as short a distance as 24 miles, as evidence by the observations between Morris and Ottawa, already introduced. The

colon contents of the Illinois River is in my opinion, especially significant from a sanitary point of view, and affords evidence in entire harmony with the conclusions derived from the chemical examinations and from the number of bacteria of all kinds shown to be present in these waters. The colon bacteria, which are found in great abundance in the waters of the Drainage Canal and in the upper stretches of the river practically disappear before Averyville is reached. (6139.)

"It is clear from the data that I have presented that the water of the Illinois river undergoes a real and very considerable purification. The colon bacteria which are shown to be present in large numbers in Chicago sewage disappear almost completely in less than 150 miles flow. Since all investigators are agreed that the colon bacillus is more hardy than its relative, the typhoid bacillus, and can live in water for a longer time there is every reason for supposing that the latter microbe dies out with at least the same rapidity. If it be true, as I firmly believe to be the case, that the fate of the colon bacillus in running water furnishes the most satisfactory indication we can secure at present of the continuance of vitality of the typhoid bacillus, there can be no hesitation as to the conclusion to be drawn from this investigation. Since this biological relative of the typhoid bacillus perishes speedily and in large numbers in the course of the Illinois River, it is my opinion that the typhoid bacillus itself cannot long survive exposure to the same conditions. (6140.)

"Danger of infection is diminished by dilution for the reason that the infected matter is spread over a large area. (6199.)

"I conclude that the sewage from Chicago, introduced into the Drainage Canal, has no injurious effect upon the waters of the Mississippi as the same passes along the shore of the State of Missouri.

"I am unable to differentiate clearly between infections

matter and pollution dangerous to public health in this connection, since polluting matters dangerous to the public health are, so far as I am aware, those able to communicate infection. I, accordingly, would answer this question in the same way as I have answered the preceding, namely, that in my opinion no infectious matter coming from the sewers of Chicago by way of the Drainage Canal reaches as far down the Illinois River as the City of Grafton. (6177.)

"It is my opinion that no pollution dangerous to public health entering the Drainage Canal from the sewers of Chicago, reaches as far down the Illinois River as Grafton. I know of no evidence, bacterial or chemical, that would justify the conclusion that polluted and infected matter coming from the sewers of Chicago would reach as far down the Illinois River as Grafton. On the contrary, the evidence of which I am cognizant points to a precisely opposite conclusion. In my judgment the Illinois River at its mouth does not contain infectious matter of a dangerous character, derived from the sewers of Chicago, and so could not be a factor in carrying infectious and polluting matters from the sewers of Chicago to the City of St. Louis. (6178.)

"From my knowledge of the conditions that obtain in Chicago and the Drainage Canal, it is my judgment that the sewage of Chicago has no injurious or deleterious effect upon the water supply of the City of St. Louis or upon the water of the Mississippi as it passes along the shore of the State of Missouri. (6179.)

"Remembering that the upper stretches of the Illinois River are highly polluted with sewage and that considerable additions of sewage are made to the Illinois River at points along its course, I do not believe that bacilli introduced into the Desplaines or upper portion of the Illinois River would live under natural conditions more than five or six days. (6239.)

"It is my opinion that a typhoid bacillus, discharged from the body of a typhoid patient in Chicago and assuming that such discharges were not disinfected so that the bacillus could pass into the sewers of Chicago and thence into the Chicago River and Drainage Canal, might live as long as three or four days after leaving the body of the patient.

"From what I know of the rate of flow in the Drainage Canal and in the Desplaines and upper Illinois Rivers, in my judgment such a typhoid bacillus would perish long before Averyville was reached, even at a period of low temperature and high water.

"The analyses and examinations that have been made of the water in the Illinois River at its mouth do not in my opinion show that the opening of the Drainage Canal has caused the sewage from Joliet, Peoria and other towns of the Illinois River to be hurried into the waters of the Mississippi River any more rapidly than was the case before the added volume of water from the Drainage Canal was poured into the waters of the Illinois.

"I do not think that such increased speed as might reasonably be assumed to result from the opening of the Drainage Canal would increase in any degree the liability to typhoid and other water borne diseases of the inhabitants of the State of Missouri for the reason that such shortening of the time involved as might legitimately be assumed to occur would not come within the range of longevity of a typhoid bacillus under these conditions. (6313.)

"In my opinion, and I believe in that of bacteriologists generally, the presence of colon bacilli in water affords a satisfactory clue to the amount and freshness of sewage pollution. (6315.)

"Since it is true that the number of colon bacilli now found in the water of the Illinois River at Grafton is no greater than the number found in the water at this same place before

the opening of the Drainage Canal, I am certainly compelled to conclude that the character of the water and its liability to contain typhoid germs has not been materially changed and that the water is no more dangerous than formerly.

"From all that I have been able to learn concerning the life history of the typhoid germ in water, it is my opinion that it is most improbable that typhoid germs would live long enough in the Illinois River to pass from Lockport to Lake Peoria. In case of such an extremely unlikely occurrence any such typhoid germs deposited on the bed of Lake Peoria would in my judgment be in an extremely weakened condition and would not be likely to live for more than a few hours. It is my opinion that there certainly would be no accumulation of bacilli under these conditions. (6316.)

"It is my opinion that typhoid fever germs coming from Chicago sewage rarely, if ever, live long enough to reach Averyville." (6317.)

Professor F. Robert Zeit after testifying about the experiments he made on typhoid longevity states:

"As result of the experiments I am of the opinion that typhoid bacilli cannot live in the Drainage Canal or in the Chicago River or in the Illinois River for more than three days.

"Q. What is your opinion, based upon all the knowledge which you possess in regard to this experiment, and other experiments made by you, as to whether the typhoid bacilli coming from the sewers of Chicago and entering the Drainage Canal and from thence into the Illinois River could survive the journey from Chicago to St. Louis, a distance of 357 miles, and be a danger and a menace to the inhabitants of St. Louis using the waters of the Mississippi River at the St. Louis intake, or the residents of Missouri using the waters of the Mississippi River, as it passes along the eastern shore of the

State of Missouri, for domestic and drinking purposes? (6437.)

"A. It is my opinion that it offers absolutely no danger to the citizens of St. Louis and that no typhoid bacillus coming from the sewers of Chicago will live to reach there."

Professor H. L. Russell testifies:

"Have examined and studied the bacterial and chemical analyses of the waters of Lake Michigan, the Drainage Canal, the Desplaines River, the Illinois River, the Mississippi River, and the Missouri River as made by Professors Jordan, Gehrmann, Palmer and Burrill, the same being published in what is known as 'Reports of Streams Examinations,' published by the Sanitary District of Chicago.

"In September, 1903, I made a trip, in conjunction with a number of other individuals, from Chicago to St. Louis, by way of the Drainage Canal, Desplaines River, Illinois River, Mississippi River, and had given me special opportunities for the physical examination of those streams.

"Taking into consideration the conditions which obtain in the Illinois River as to sedimentation and dilution, and all other conditions that can be observed, which permit of the production of chemical and bacterial changes in the sewage, as revealed by the analyses reported in Streams Examinations, I do not consider that the sewage of Chicago, as discharged into the Drainage Canal, can have any material effect upon the waters of the Mississippi River except possibly to increase the amount of such undissolved salts as chlorine which are not taken out of solution and which would therefore find their way down the stream and thus probably increase the chlorine content of the waters of the Mississippi River as they pass the shores of the State of Missouri.

"Basing the results which have been recorded on the self-purification of flowing streams on the fact that the typhoid organism does not thrive in natural waters, and it is only

a question of how long it will live in waters of this class, that the time of flow is so great that pollution dangerous to public health would cease to exist in sewage passing from the City of Chicago to the Illinois River, down as far as the Town of Grafton, from the fact that experimental evidence shows that the typhoid organism will not live in highly polluted waters like those of the Drainage Canal and upper portions of the Illinois River for more than a brief period of time, measured by three or four days, my opinion is that any pollution which would be dangerous to public health which might arise from the sewers of Chicago and enter the Drainage Canal would not exert any influence on the character of the waters of the Illinois River at its mouth, at the Town of Grafton. (6493.)

"The evidence which can be adduced for the justification of the conclusion just expressed rests upon experimental evidence which has been adduced, which shows that organisms capable of causing typhoid fever will not live in the waters of the Illinois River for a sufficient period of time so that it would have been possible for them to have been carried from the sewers of the City of Chicago down the Illinois River as far as Grafton.

"My opinion is that any infectious matters which may be discharged from the sewers of Chicago by way of the Drainage Canal, are deprived of their infectious properties by reason of the conditions which exist in the waters of the Drainage Canal and in the waters of the Illinois River before they have had time to have been carried by the waters of said stream from the City of Chicago down through the Drainage Canal and the Illinois River to the City of Grafton. (6493.)

"If the typhoid fever is destroyed under natural conditions which obtain in the Illinois River, in the course of three or four days, the stage of water in the Missouri River and the Mississippi River would exert no effect as I can see on the

carrying of infected or polluted water from the City of Chicago to the City of St. Louis. (6494.)

"From the knowledge which I have gained with reference to other conditions which exist in the waters of the Chicago Drainage Canal and in the waters of the Illinois River, together with the evidence which has been presented as to the degree of purification which obtains in that stream, as reported by the chemical and bacteriological examination made of the waters of the Drainage Canal and Illinois River and the Mississippi River, down to the intake tower at the Chain of Rocks, at the City of St. Louis, I do not consider that the introduction of the sewage of Chicago into the Drainage Canal exerts any deleterious effect upon the water supply of St. Louis or upon the waters of the Mississippi River as they pass the State of Missouri. (6496.)

"In view of the above experiments and other conditions, I am of the opinion that typhoid organisms finding their way through the sewers of Chicago, into the Chicago River and thence into the Drainage Canal, down the Desplaines and into the Illinois River would be destroyed before such water had passed the course of the Illinois River. (6522.)

"The chemical and bacteriological evidence which has been secured in this case through the experimental and observational data which have been presented justify, in my judgment, the conclusion that the waters of the Illinois River at Grafton show no indication whatever of unpurified sewage from Chicago that has found its way from Chicago to the latter place.

"Taking into consideration the time involved in the flow of water from Chicago to St. Louis, and in view of the evidence which I have previously presented in combination with others that the typhoid organism is incapable of retaining its vitality for the period of time assumed in the foregoing question, I would say that I know of no evidence based upon any

analysis, experiments or otherwise that would justify the assumption that typhoid organisms deposited in the Chicago Drainage Canal will pass by way of the Illinois River into the Mississippi River and find their way into the water supply of the City of St. Louis at the intake tower at the Chain of Rocks. (6571.)

"Assuming that a typhoid fever epidemic of extraordinary proportions should prevail in Chicago, no effect would be produced upon the people who use the Mississippi River water for drinking purposes. (6574.)

"Taking into consideration the chemical and bacterial knowledge which has been derived from actual experiment and also all knowledge which I possess with reference to the conditions which would obtain when the sewage of Chicago was placed in the Drainage Canal, and taking into consideration the possible variation which would exist at different seasons of the year and the influence which different stages of water would exert upon the vitality of disease organisms which might be present in such sewage, it is my opinion that the introduction of such sewage into the Illinois River would not be a danger and a menace to the inhabitants of the State of Missouri and the citizens of the City of St. Louis who might use the waters of the Mississippi River at the intake tower, Chain of Rocks. (6575.)

"From the analytical data which has been presented, it is shown that the addition of the sewage of Chicago to the waters of the Drainage Canal results in such a degree of purification that I do not think that deleterious substances or infectious matters capable of producing disease would be found in the waters of the Illinois River at the City of Peoria, which were derived from the sewers of the City of Chicago. The dams in the Illinois River are an aid to sedimentation and such sedimentation results in the elimination of a large proportion of the total bacterial life. (6576.)

"The water of the Mississippi River at the Chain of Rocks prior to January, 1900, was not to be regarded as a thoroughly safe and potable water supply suitable for all domestic and drinking purposes." (6578.)

Professor Erastus G. Smith testified as follows:

"Q. From your knowledge of the physical conditions that obtain along the Illinois River as well as your knowledge based upon the study of the results of the analysis as they appear in Streams Examinations on the water both chemical and bacterial of the Illinois River, what effect, if any, does the sewage from Chicago discharged into the Drainage Canal have upon the waters of the Mississippi as the same passes along the shore of the State of Missouri?

"A. In my opinion all the conditions affect the quality of the Illinois River. Its physical surrounding; the study of the chemical analyses, the comparison of the bacterial analyses; the death rate of the typhoid bacillus; the rate of flow of the river, the Illinois River as discharged into the waters of the Mississippi does not affect its quality as it passes along the State of Missouri, in fact the data probably indicate that the Mississippi River is not of as good quality as the Illinois River itself in its lower reaches. (6759.)

"In my opinion it seems to me quite clear that there is no pollution dangerous to public health from the Drainage Canal which receives the outfall from the sewers of Chicago which reaches down the Illinois River as far as Grafton.

"There are several factors in connection with the river and the study of the agencies at work in the self purification of the stream in my opinion would justify that statement. We have the agencies of dilution of the sewage whereby the sedimentation of the river is augmented for the reasons previously outlined.

"We have the experimental work showing the short life

probably not exceeding three days of the typhoid bacillus in the waters of the river.

"We have the rate of flow of the river showing that the time required for substances to pass from the Drainage Canal at Chicago to Grafton considerably exceeded the life period of these organisms as revealed by the special experiments upon the typhoid bacillus of this particular river.

"We have further the study of the river from a chemical standpoint which shows the purification of the river from that standpoint and we have also the data from the bacteriological investigations all a matter of evidence which show that the waters have purified themselves from the bacterial standpoint. That is, the waters of the Illinois River at Grafton appear from the chemical and bacteriological standpoints as evidenced by these data to be of the quality of other rivers of this section.

"To sum up these conclusions, in my opinion, the several agencies at work make the Illinois River at Grafton about a normal river water in this section. (6760.)

"It is my opinion that infectious matters coming from the sewers of Chicago by way of the Drainage Canal do not reach as far down the river as Grafton, for the reasons I have outlined in my answer previously given. It is my opinion that the low water in the Missouri River at a time when there was high water in the Illinois, would not be a factor in carrying infected and polluted matters from the sewers of Chicago to St. Louis, because the waters of the Illinois River have become purified through the process of self purification and removed the infected and polluted matters and therefore, the condition of the Missouri River does not enter into the discussion. (6761.)

"For the reasons given above, the agencies which are at work in the Illinois River tending to the self purification of the stream and the removal of sewage material as such from

the river it is my opinion that the sewage from Chicago does not affect the water supply of the City of St. Louis or the waters of the Mississippi River as they pass along the State of Missouri. (6762.)

"From the experiments all a matter of evidence it is my opinion that the typhoid bacilli passing from the sewers of Chicago into the Chicago River, thence into the Drainage Canal are destroyed in a short period, not exceeding more than 3 or 4 days after passage into the Desplaines and Illinois Rivers. (6763.)

"It is my opinion from all the knowledge that I possess from a study of the analytical data and the conditions surrounding the river that typhoid bacilli coming from the sewage of Chicago and entering the Drainage Canal could not traverse that distance and survive. This being true they could not possibly be a danger and a menace to the inhabitants of the State of Missouri using the waters of the Missisippi for drinking and domestic purposes.

"The sewage of Chicago, in my judgment, being eliminated from the stream owing to the processes of self-purification before the Illinois river reaches Grafton, the matter of the settling basins at St. Louis does not enter into the problem of the purification or non-purification of the sewage of Chicago, if not reaching that point as undecomposed sewage. (6766.)

"In studying the tables of analyses submitted in evidence, it is my opinion that the waters of the Illinois River begin to show a very decided purification at Ottawa, which increases and reaches its maximum at Averyville, which is above the City of Peoria. It receives, at Peoria, and at Pekin, a considerable addition of sewage material; another area, or a zone of purification commences at this point, some distance 30 miles or so below, and is practically completed at Grafton,

the river at that point appearing to be water of the quality of rivers of this section. (6772.)

"In my opinion, polluted and infected matter coming from the sewage of Chicago through the Drainage Canal, would have become harmless before reaching Peoria and would have been altered so that it would not be deposited on the bottom as sediment as infectious material. The bacteriological data already submitted in evidence, in my opinion and judgment, show the purification of the stream before reaching Peoria. (6773.)

"The chemical and bacterial data already a matter of evidence in this case, showing that the waters have become practically purified before reaching Peoria, it would be my opinion that sewage from the City of Chicago could not be a menace to the inhabitants of the State of Missouri and the citizens of the City of St. Louis using the Mississippi River water.

"By comparison of the data submitted by Professors Long, Palmer, Burrill and Jordan, it is my opinion that the Illinois River at Grafton discloses the least amount of impurity or pollution of the three rivers, the Illinois, Mississippi or the Missouri.

"It would be evident that if the Illinois River is of a better quality or does not show as much impurity as either of the other rivers, it would really benefit them, if anything, and in proportion as the waters became mixed. If the evidence should be that the Illinois River practically hugs the east shore and does not mix, particularly it would not affect them. If, on the other hand, the data should show that there is a gradual mixing then in proportion as this mixing occurred to that degree it would improve, if anything. The differences are not very great, however, between the data as I have examined them. (6774.)

"From examinations of the Mississippi River water made

at different times throughout a series of years, and at different points reaching from Brainard, Minnesota, as far down the river as Muscatine, it is my opinion that the Mississippi River water in its raw and untreated condition is unfit for use as a public water supply, without treatment, and it is my opinion, therefore, that the mixing of the Illinois River with the Mississippi River water, after it may have received the Missouri River, does not create any added danger to the inhabitants of St. Louis and to the people of Missouri, for public, and domestic purposes. (6783.)

"From all my knowledge of conditions that obtain along the Illinois River, from the inspection of the river throughout its entire length, from study of the analytical data, both chemical and bacteriological, already a matter of evidence in this case, from the rate of flow of the river, from the data adduced regarding the duration of life of the pathogenic germs the same not living more than three or four days in the waters of the stream, with the processes of self-purification at work, notably the process of dilution and sedimentation, and the chemical and bacterial changes shown, it is my opinion that infected matter and pathogenic germs coming into the Drainage Canal from the sewers of Chicago would not reach as far down the Illinois River as the City of Peoria." (6784.)

"In view of all the knowledge which I possess upon the Illinois River, and the study of its physical characteristics, from the study of the chemical and bacteriological analyses of the river already a matter of evidence in this case, from the rate of flow of the river and the duration of life of the typhoid bacillus, the same not extending over a period of three or four days, as already a matter of evidence, from the analytical and self-purification operative in the river, notably those of dilution, sedimentation and the bacterial and chemical changes which the river undergoes, it is my opinion that the sewage of the City of Chicago, entering the Drainage

Canal, and thence discharged into the Illinois which in turn empties into the Mississippi River does not constitute a menace and a danger to the inhabitants of the State of Missouri, or to the citizens of the City of St. Louis taking their water supply from the Mississippi River." (6785.)

"The effect of increasing water at flood tide from the tributaries of the Illinois River, as well as the Illinois River itself, coming in at points below the entrance of the polluted waters of the Drainage Canal would and do cause, as I have observed personally, a large area of land to be overflowed along the Illinois River Valley, and the effect of this overflow is to greatly increase the area of sedimentation so that the sewage from the City of Chicago entering the river through the Drainage Canal would have an opportunity for more complete sedimentation; this overflow forms an important factor in estimating the significance to be attached to the element of sedimentaion in the purification from the sewage in the stream. It is my opinion that if the volume of water be increased overflowing this greater area of territory, the waters discharging out, becoming retarded in their course, and giving opportunity thus for the sedimentation, it would follow that the sedimentation would be greater when the volume of water was sufficiently large to cause the overflow of a considerable section of territory adjacent to the Illinois River through the valley." (6787-8.)

"It is my opinion that prior to January, 1900, the water of the Mississippi River at the Chain of Rocks was not safe and potable drinking water. (Same as to the Missouri and Illinois Rivers.)

"From my study of the conditions of the river, especially from the study of the chemical analyses of the supply of water, and also the bacteriological conditions of the water of the river as disclosed by such analyses from before and after the opening of the Drainage Canal, I am of the opinion that

the sanitary condition of the Illinois River water has not been materially changed by the opening of the Canal.

"I have acted as chemist for the American Water Works Company operating the public water plant at the City of Omaha, and also for the Water Company at Council Bluffs, Iowa, across the river from Omaha, both cities taking their water from the Missouri River.

"I am of the opinion that the sewage discharged through the Drainage Canal, has no material effect upon the waters of the Mississippi and Missouri Rivers at the Chain of Rocks. Such changes as it does effect are those due to the mineral salts carried on by the river, as chlorides and nitrates. It is my opinion that the sewage as such, does not reach the mouth of the Illinois River in an unchanged condition.

"I have prepared a table of averages based upon the analytical data presented in evidence in this case by Professors Jordan and Palmer, from various points along the Illinois River, the Missouri River and the Mississippi River. (Which table is reproduced on page 6798.) (Witness explains the terms used in table.)

"In a word the important fact brought out (by this table) is that the waters have undergone a practical degree of purification when they reach Grafton, and the analytical data clearly show that the water in 1900 was of a quality superior to that in 1899, for these dates given.

"Applying the same principle to the averages of the results of waters taken from the Mississippi River at Grafton, it is my opinion that the waters of the Illinois River at Grafton, as they empty into the Mississippi River, are better than the waters of the Mississippi River taken from the river at a point above Grafton.

"Applying the same principles of interpretation of the analyses, it is my opinion that the waters of the Illinois, as de-

livered into the Mississippi River at Grafton, are of a quality, upon these dates for which these averages are given, and they were the only dates from which data were available, which covered similar periods and similar seasonoble fluctuations of the stream, and comparing these data the waters of the Illinois as delivered into the Mississippi at Grafton, are upon the whole a better water, chemically, for drinking and domestic purposes than the samples taken from the intake at St. Louis, the water of the intake of St. Louis being the waters of the Mississippi River after it has received the flow from the Illinois and the Missouri Rivers.

"I have studied the bacterial tables as submitted by Prof. Jordan and Prof Burrill and have made a tabulation of results as given by them in their tables, which is already a matter of evidence." (6803.)

"From the results shown by this table, it is my opinion that the Illinois River is better in the number of bacteria contained in the same, than the Mississippi or Missouri Rivers at any of the points named in said table. Taking everything into consideration and including all of the agencies of purification, sedimentation, etc., I am of the opinion that the combination of these agencies all tend to practically purify the Illinois River so that sewage, as such, does not reach down that river as far as Grafton, and, further. (6809.)

"I was employed by the Peoria Water Company, at the time of the installation of their new plant in 1892 and I made some analyses of the Illinois River and some investigation as to its sanitary condition at that time. In the course of the investigation made at that time the river was, in my opinion, unfit for use as a public water supply, and at my advice the company dropped the consideration of the stream for that use. In my opinion the water at the present time is of a better quality than it was at that time, in 1892. In the course of those investigations I was upon the river in a boat and went out to

and across the wagon bridge observing the river from time to time, and samples were taken for chemical analysis from the river. It was of a dirty appearance, as I re[illegible], and possessed, in warm seasons, a decidedly disagreeable odor. The last time I observed the river at Peoria was in September, 1903. (6811.)

"I am of the opinion that the water supply of St. Louis is not contaminated, polluted or injured by the sewage of Chicago entering the Drainage Canal and thence into the Illinois River. (6813.)

"It is my opinion that sewage from the City of Chicago becomes practically purified at Grafton and the quality of the Illinois is fairly comparable with that of streams forming its tributaries, and that the sewage of Chicago has become purified practically, the pathogenic bacteria having been eliminated in the process of flow of the stream, and hence the original organic matter of the sewage from Chicago does not find its way into the intake tower of the St. Louis water works at the Chain of Rocks.

"I am of the opinion that the typhoid bacillus would not reach as far as Lake Peoria and therefore water leaving Lake Peoria could not possibly contain more infectious and dangerous pollution than is at present in the diluted sewage entering the Bear Trap dam at the foot of the Canal. (6818.)

"From all data available concerning the character of the water of the Illinois River, the agencies at work in the river affecting chemical and bacterial changes, all evidence showing a bacterial purification of the river at Lake Peoria, and added to this the positive results from experiments instituted and carried out by Dr. Zeit, Dr. Jordan and Dr. Russell, I am very clearly of the opinion that typhoid fever germs coming from Chicago sewers do not reach the lakes and slack water portions of the Illinois River above Peoria." (6819.)

Prof. W. P. Mason testified:

"I have examined and studied the bacterial and chemical analyses of the waters of Lake Michigan, the Drainage Canal, the Desplaines River, the Illinois River, the Mississippi River, and the Missouri River as made by Professors Jordan, Palmer, Gehrmann and Burrill, the same being published in what is known as reports of Streams Examinations, published by the Sanitary District of Chicago. I am acquainted with the Chicago River, the Drainage Canal, the Desplaines River, the Illinois River, and the Mississippi River from Grafton to St. Louis. I went on a boat from the water front to Lockport, down the Drainage Canal, by daylight. I afterwards followed the course of the river in trolley and on train as far as La Salle and then took a steamer and went from La Salle in daylight to St. Louis, tying up at night so that no places were passed in the dark. On arrival at St. Louis, I visited the settling basins and saw them being cleaned. I have made a special study of bacteriology as applied to water investigations.

"My opinion is that the waters of the Illinois do not have any appreciable effect, good or bad, upon the waters of the Mississippi River into which it flows.

The Illinois River has no appreciable sanitary effect on the Mississippi, although it is possible it may slightly improve the mixture, inasmuch as if there is any difference between the Illinois at Grafton, and the Mississippi River at Grafton and the Missouri River above the junction, that difference is in favor of the Illinois River at Grafton. I believe a typhoid bacillus passing from the sewers of Chicago would die before Grafton was reached.

"My opinion is that typhoid fever bacilli coming from the sewers of Chicago would not be a danger and a menace to the inhabitants of St. Louis using the water of the Mississippi for drinking and domestic purposes." (6916-21.)

Witness then states that he has prepared a chart of coli determinations based on Prof. Jordan's tables for the year 1901. He then states:

"Judging from the bacillus coli communis contents of the several waters, operating upon 1 c.c. as stated, the relative purity of the waters in question would stand, first in purity, Illinois River at Grafton; (2) Mississippi River at Grafton; (3) Illinois River at Averyville; (4) Missouri River at Bellefontaine; (5) Mississippi River water at the St. Louis intake and (6) the Illinois River at Pekin. (6935.)

"Basing my reply on the bacilli coli communis contents, the Illinois River at Grafton is the most pure. The Mississippi River at Grafton is next and the Missouri River at Bellefontaine is the least pure.

"I do not think that typhoid germs coming from Chicago through the Drainage Canal and deposited on the bottom of the Desplaines and Illinois Rivers, between Chicago and Peoria, would be able to retain their dangerous qualities after such a discharge in the bottom of the river. I do not think the sewage from Chicago passing through the Drainage Canal into the Illinois River at different seasons of the year and at different stages of water in the Illinois River would be a danger and menace to the inhabitants of Missouri and the citizens of St. Louis using the water of the Mississippi. From the data introduced in evidence in this case, my opinion is that of the three rivers—the Illinois, Mississippi and Missouri, the Illinois represents the least impurity, although I do not consider that there is any considerable difference between the three, what little difference there is being in favor of the Illinois. The emptying of the Illinois River into the Mississippi River makes no material change in the character of the combined waters. What little change there is, is an improvement, but as I have already stated, the three waters are not widely apart. They are all about the same, any difference being in favor of the Illinois. (6938-40.)

"My opinion is that the water supply of St. Louis is not contaminated by the sewage of Chicago entering the Drainage Canal. The water of the Mississippi River at the Chain of Rocks prior to January 1, 1900, was not a safe and potable drinking water fit for domestic and drinking purposes after passing through the settling basins. The sanitary condition of the Illinois River at Grafton has been improved by the opening of the Canal. The sewage discharged from the Drainage Canal has no appreciable effect upon the waters of the Mississippi and Missouri Rivers at the Chain of Rocks. (6944.)

"I have no knowledge of the presence of infected Chicago sewage in the Illinois River at Grafton, and I believe that the use of the water of the Mississippi at the Chain of Rocks, because of the admixture of water from the Illinois River, would not be a menace to the health of the inhabitants of St. Louis. I do not consider that the waters of the Illinois River under the conditions obtaining, commingled with the waters of the Mississippi River, are a menace to the inhabitants of the State of Missouri living upon the Mississippi River and using the Mississippi River water for drinking purposes at points on the Missouri shore. Assuming that the only pollution upon the watershed of the Mississippi and its tributaries above the intake of St. Louis was that derived from the Sanitary District of Chicago, and having in mind the large amount of typhoid fever in Chicago, I do not believe that dangerous infection and dangerous pollution might, under existing conditions, find their way into the water supply of St. Louis."

Dr. Lewellys F. Barker testified:

"If one takes the extreme statement of one investigator, the maximum distance that contagion of typhoid fever has been shown to travel in a flowing stream, is about 70 or 75 miles. That view and assertion have not met with general

acceptance, however. Am acquainted with the general conditions which obtain in Chicago, the Drainage Canal, the Illinois River, the Mississippi and Missouri rivers down to St. Louis. In my opinion a typhoid bacillus lying in the sediment of a stream for a period in excess of sixty days, would be harmless. In my opinion, pathogenic bacteria in the sewage of Chicago would not be able to survive the journey, taking into consideration the sewage discharged at Peoria and Pekin, etc., into the river. In my opinion, the sewage entering the Drainage Canal, which empties into the Illinois River and hence into the Mississippi, would not be a menace and danger to the inhabitants of the State of Missouri and the citizens of St. Louis, taking their water supply from the intake tower at the Chain of Rocks. Assuming an epidemic of Asiatic cholera in Chicago, the germ would not survive the journey from Chicago to the intake tower at St. Louis. The introduction of this mass of organic material from the stockyards and distilleries of Peoria would favor the disappearance of the typhoid bacillus.

"There would be no danger of infection by tetanus or enteriditus sporogones. As to the statistics referred to, I can see no connection between the opening of the Drainage Canal and the figures. The probable length of life of the typhoid bacillus introduced by way of the Drainage Canal into a sluggish River, such as the Illinois River, flowing through a more or less densely populated country, and receiving successive increments of organic matter together with the associated saprophytic bacteria, I should think would be from five to seven days." (7102-3.)

Prof. Theobald Smith testified, beginning on page 7291:

"In view of the fact that our methods are still unsatisfactory in the isolation of the typhoid bacillus, at least not practicable on a large scale, the colon bacillus affords us the best indication of the possible presence of the typhoid bacillus.

"I know of no other group of bacilli but the colon, whose life in water is more likely to furnish an index as to the life of the typhoid bacillus. I am familiar with the figures and the data introduced by Prof. Jordan in this case, relative to the colon bacillus in the waters of the Drainage Canal and the upper Illinois River.

Prof. Theobald Smith testified, beginning on page 7291:

"I made a particularly careful examination of his tables as to the result of his examination of the Illinois River at its mouth, and of the Mississippi and Missouri Rivers. From these tables, I should assume that the colon bacilli had very largely disappeared in their passage down the Illinois River and that the colon content of the Illinois River at Grafton is therefore less than that of the Missouri and the Mississippi Rivers, or at least about the same. That is to say, the colon content of the Illinois at Grafton is not to any material degree superior to that of the tributaries of the Illinois River, and it is, on the whole less than the colon content of the Mississippi River and the Missouri River according to these tests. It would seem that the condition of the water at the mouth of the Illinois River was certainly not inferior, if not superior to that of the Mississippi River and the Missouri River, at these points, as I read the testimony in these tables. The Missouri River is, on the whole, more polluted than the Illinois River. According to these figures, there is not very much difference, but the benefit of the doubt rests with the Illinois River without any question. Basing myself upon the colon tests, as I certainly should in all such examinations, I should make the table speak for itself. So far as these colon determinations go, and so far as the inference drawn from the colon is warranted, I should say that the Illinois River was superior in its sanitary quality to either of the other Rivers, the Mississippi and Missouri.

"According to these tables, there is an enormous de-

struction of colon bacilli down to Averyville in the Illinois River, and basing myself upon these, I should say that a similar, if not greater destruction of the typhoid bacilli had taken place down to that point.

"It would seem to me that the disappearance of the colon bacilli indicates that excluding a large amount of sewage which enters below Chicago the typhoid bacillus would probably be entirely eliminated during that long course from Chicago to the mouth of the Illinois River of three hundred and fifty odd miles.

"I know of no bacteriological evidence that affords more suitable indications than the one in question, to-wit: the colon determinations.

"If a typhoid bacillus was found at St. Louis, it would be utterly impossible to identify the source of such typhoid bacillus. The presumption would be that the typhoid bacillus would come from the nearest sewage discharging town.

"It seems to me that considering the enormous destruction of the colon bacillus from Chicago down to Averyville, the very great influx of sewage at Peoria, that the presumptive evidence is very strong that the typhoid bacillus from Chicago would not reach St. Louis because it is highly probable that the colon bacilli at the mouth of the Illinois River are probably those that have been introduced further down the stream, say at Peoria and other sewage-discharging places." (7291-7301.)

Prof. Leonard P. Kinnicutt, a chemist, and an expert on septic tanks wherein sewage undergoes purification, testifies as follows:

"As I passed along the Sanitary Canal in a tug boat from Chicago to Lockport (in September, 1903), I took particular notice of the indications of the Sanitary Canal acting as a septic tank. Among the chief indications that it was so act-

ing was that gas was being given off and I noticed bubbles of gas given off from the liquid as far as Lemont. After passing Lemont I noticed no further development taking place. The odor from parts of the Sanitary Canal, especially near Chicago, remind you of the odor from the septic tank. Further down there was the odor that you obtain where the effluent of a sedimentation tank passes over or is allowed to fall over rocks or passes over a dam. (7342.)

"From the analysis that I have made showing the character of the water in the canal at Kedzie avenue, these results indicate very strongly that the septic action has taken place during the passage of water containing sewage through this Canal; * * * that the results agree in their general characteristics with results that have been obtained by the examination of crude sewage and the effluent from the septic tank in the various places that I have given in table E. The changes are exactly the same in character, the difference only being in amount.

"This septic action has a purifying effect upon the sewage of Chicago as it passes through the Drainage Canal. It also renders the substances which still remain in the sewage more easily acted upon when the sewage enters the river, and it purifies the sewage by removing a part of the solid matter that was in the sewage, by throwing it down to the bottom of the canal and by the removal of part of the solid matter by changing it into gas.

"I have studied the chemical data prepared by Prof. Long and the chemical and bacterial data prepared by Prof. Jordan, Palmer, Burrill and Zeit heretofore introduced in evidence, also the tables introduced in evidence by these witnesses.

"I have taken the analytical data as given by Professor Long in the Illinois State Board of Health, 1901, which are the results of his examinations of the water at the various sta-

tions from Chicago to Grafton on the Illinois River both for 1899 and 1900."

The witness then draws the following conclusions from the tables drawn by Prof. Long for the year 1899. (7354.)

"Table 8, Ottawa, Illinois River: There has been a very decided change in the purity of the water in the river between Morris and Ottawa, a distance of about 24 miles. The chlorine shows that there has been very little dilution of the water of the river between these points, and the very decided decrease in free and albuminoid ammonia with increase of nitrogen as nitrites and nitrates shows that bacterial decomposition of the organic matter is rapidly taking place, changing the organic matter into mineral matter. There has also been a certain amount of decomposition of suspended matter. Between Morris and Ottawa there is a dam, the Marseilles dam, I believe, but this would have little effect in the character of the water beyond bringing about the removal of suspended matter, there being, according to Prof. Palmer's results, dissolved oxygen in the water. (7356.)

"Table 10, La Salle, Illinois River: * * * shows that during the stretch of river between Ottawa and La Salle the processes of purification have been very active.

"Table 12, Henry: The slight increase in chlorine would indicate a silght addition of sewage to the river, probably from La Salle and Peru, total population 20,000. There has, however, been only slight changes between. (7357.)

"Table 13, Peoria Narrows: The chlorine shows that there has been more or less dilution between Henry and the Narrows, but the great change has been in the removal of free principal change between Henry and the Narrows has been ammonia and nitrogen as nitries. This shows that the the last process in the changing of the organic matters of sewage into mineral matter.

"Table 14, Wesley City: * * * shows that a large amount of organic matter has been added to the river between Peoria Narrows and Wesley City, a distance of only about six miles. This addition from my knowledge of the river, is from the Town of Peoria, 50,000 inhabitants, with its large cattle sheds and distilleries.

"Table 15, Pekin: The distance to Pekin from Wesley City is about ten miles, yet in this stetch, a great amount of purification seems to have taken place, much more than I should have expected. * * * There is no marked dilution as shown by the amount of chlorine.

"Table 16, Havana: We see here, as at Peoria Narrows, the final changes of organic matter into mineral matter taking place.

"Table 26, Grafton: The distance from Havana to Grafton is 119 miles. There is a dam between Grafton and Havana and the water of the river is diluted by the Spoon and Sangamon Rivers, both of which enter the Illinois between Havana and Grafton. The water at Grafton, as shown by the analyses, has been so purified between Havana and Grafton that it now closely resembles the water at Peoria Narrows. It shows only in the chlorine and nitrogen as nitrates evidence of part pollution.

"I have also prepared tables from the results of Professor Long's analyses at the various stations from Chicago to Grafton, from June to October, 1900.

"Table 44, Lockport Canal: This analysis when taken in connection with table 43, as I have already pointed out, shows that the dilute sewage has undergone very decided changes in its passage through the Canal.

"Table 45, Joliet, Desplaines River: This analysis shows that the water is not as pure as it has been up there, but when compared with the analyses made in 1899, shows that it contains very much less organic matter than it did at that time.

"Table 46, Morris: The dilution by the waters of the Kankakee is here shown by the chlorine as in 1899. The water is very much purer than in 1899. (7359.)

"Table 47, Ottawa: There has been even more marked purification of the water in its run of 24 miles in 1900 than 1899, as shown by the reduction of free albuminoid ammonia, and oxygen consumed, and by increase of nitrites and nitrates. That there has been little, if any dilution, is shown by the chlorine.

"The water is much purer than in 1899.

"Table 49, La Salle: The purification which was noted at Ottawa has continued. The chlorine shows the effect of slight dilution. River much purer than in 1899.

"Table 51, Henry: The results similar to those obtained in 1899, the slight increase in chlorine, indicates the addition of the sewage of La Salle and Peru. Slight changes as regards organic matter. River purer than in 1899.

"Table 52, Peoria Narrows: The change as was the case in 1899, is the decrease in free ammonia, albuminoid ammonia and nitrogen as nitrites. Water much purer than in 1899.

"Table 53, Wesley City: The analyses show the addition of the sewage of Peoria.

"Table 54, Pekin: As in 1899, a great amount of purification seems to have taken place between Wesley City and Pekin, a distance of 9 miles. River much purer than in 1899. (7360.)

"Table 55, Havana: We have here in the 24 miles similar results to 1899, a very slight increase in free ammonia and in nitrates, and a slight decrease in albuminoid ammonia. Mackinaw Creek enters the river above Havana.

"Table 58, Grafton: The water between Havana and Grafton has been so purified that the nitrates and chlorine are the only indications of the pollution of the river at Peoria."

This witness also compared tables from examinations made by Profs. Jordan, Palmer, Burrill, Zeit and Long reproduced on pages 7363 of the record. He also has made charts for the years 1899 and 1900 showing the results of these examinations. He then states (7383):

"Taking the two charts together—No. 1 and No. 2.—I draw the folowing sanitary conclusions:

"The curves on the chart representing the river from June to January, 1899, closely resemble the curves given on the chart representing the river from January to June, 1900, showing that the general character of the purification that took place is the same for the two years, the small differences being chiefly due to the effect of dilution and to seasonable variations that take place in the river. Both charts show by the rapid decrease of free ammonia, albuminoid ammonia and oxygen consumed, and increase of nitrogen as nitrates, the purification that takes place between Joliet and Ottawa, in both years, and that the zone of the most active decomposition of organic matter has not been shoved, or been pushed further down the river by the increasing volume of the river, due to the opening of the Sanitary Canal. The purification is then shown to continue in both years as the river flows to Averyville, as shown by the decrease in the free ammonia, albuminoid ammonia, oxygen consumed and nitrogen as nitrates. The chart for June to January, 1899, shows by the slight increase in albuminoid ammonia and oxygen consumed between La Salle and Henry that a certain amount of organic matter enters the river at this point, but the continued decrease of free ammonia and nitrogen as nitrites indicates that it is either not very large in amount, or of a character not easily decomposed. In both periods between La Salle and Henry, the nitrogen as nitrites shows a slight decrease, the nitrogen as nitrates also decreasing. The decrease of nitrogen as nitrates at this point is probably due to algae or green plant life. The rise in free ammonia, albuminoid ammonia, and

oxygen consumed, between Averyville and Wesley City show the pollution which enters the river between these two points in both years, which is removed in both years, as shown by the decrease in these substances as the river flows downward to Grafton. The river in both years, as shown by the curves, purifies itself again between Wesley City and Grafton, as it did between Joliet and Averyville.

"I have prepared a chart based upon the bacterial tables of Professors Burrill and Jordan for the months of May to December, inclusive, for 1899.

(The chart is reproduced on page 7386 of record.)

"The study of this chart, in connection with the chart for the chemical data of the same period, show a striking agreement between the chemical and bacterial data. The bacteria, which number over 1,000,000 per c. c. at Joliet, decrease very rapidly to La Salle. In this distance, of about 62 miles, the number has fallen from 1,000,000 to 17,412 per c. c. This shows, as did the chemical results, that the zone of the greatest purification is near Ottawa. There is a slight rise in the number of bacteria of only 2,000 per cubic centimeter between La Salle and Henry, a rise coincident with the rise for albuminoid ammonia in the chemical chart for the same period. From this point the number falls steadily until Averyville is reached, the number there being 4,756 per cubic centimeter. Then on account of the pollution entering the river at Peoria, the number rises immediately to 995,503. This sudden rise in the number of the bacteria shows how quickly sewage pollution can be detected by bacterial examination. From this point the number of bacteria rapidly falls and at Kampsville there are only 7,457 per cubic centimeter, showing the great purification that has taken place between Wesley City and Kampsville. Between Kampsville and Grafton there has been, as was the case between La Salle and Henry, a very slight increase in the number of bacteria, 2,005 per cubic cen-

timeter. This increase is not at all significant, as a slight increase at his point, after the rapid decrease between Wesley City and Kampsville is absolutely without significance as regards the problem of stream purification." (7387.)

"I have prepared a chart based upon the bacterial tables which I have prepared from tables of Professors Burrill and Jordan, already introduced, for the months of January to June, 1900. (The chart is reproduced on page 7389 of the record.)

"This chart shows the amount of bacteria at Joliet to be about 900,000 per cubic centimeter, falling to 110,000 at Ottawa, showing that the greatest amount of purification took place, exactly as it did in 1899, in the neighborhood of Ottawa. Between Ottawa and La Salle there is a slight increase in bacteria, corresponding to the slight increase in the oxygen consumed, as shown in the chart representing the chemical data for this same period. From Ottawa to Averyville the number of bacteria rapidly decreases until at Averyville one cubic centimeter contains about 45,000 bacteria. At Wesley City there is an increase in bactera amounting to 60,000 and which continues to increase until Pekin is reached. This increase, due to pollution, was shown in the curve for albuminoid ammonia, in the chart representing the chemical curves for the same period. The rapid purification in the spring months does not begin until after the river passes Pekin. From Pekin to Havana the curve falls rapidly, showing that great purification has taken place. From Havana to Beardstown there is an increase in bacteria, followed by a quick decrease, the number at Kampsville being only about 40,000. From Kampsville to Grafton there was, as in 1899, a slight increase in the number of bacteria, but the number at Grafton is less than at Averyville, showing the removal of the polluting material entering the river at Peoria. As was to be expected, the number of bacteria in the lower stretches of the river, as shown

by this curve, is greater during the summer and autumn months of 1899, than in the spring months of 1900. The soil bacteria washed into a stream during the late winter and early spring months, always increases largely the number of bacteria in a river during that period. (7390.)

"I have prepared tables showing comparisons of the sanitary character of the tributaries of the Illinois River, based upon the chemical results at their mouth, with the Illinois River at Grafton, based upon the tables of Professors Jordan and Palmer, for the months of June to December, inclusive, 1899.

"I have prepared a chart based on the tables which I have just introduced. (The chart is reproduced on page 7396 of record.)

"The chart requires very little explanation, as it is seen by the eye, that the waters of the Desplaines, the Kankakee, the Fox at their mouths, the Mississippi at Grafton, the Missouri at West Alton, contained in 1899 as much or more albuminoid ammonia and oxygen consumed than the Illinois at Grafton. The higher nitrogen as nitrates in the Illinois River, shows that the Illinois River at Grafton contained at one time higher up on the stream more organic matter, which has undergone decomposition, than did the other rivers. The free ammonia and nitrogen as nitrites is slightly higher in the Illinois at Grafton than in these other streams mentioned, with the exception of the Sangamon, but the amount in the Illinois is low, about 0.23 parts free ammonia and 0.047 parts nitrogen as nitrites, and is without any parteular significance. As regards the purity of these streams, as shown by chemical charts and data, and by these curves, I should say that the waters of these various rivers were about in the same condition in 1899 as the Illinois River at its mouth, with the exception of the Missouri River at West Alton (above its mouth), which contains more organic matter. (7397.) I have

prepared a bacterial chart from the same tables which I have just introduced, based upon the results obtained by Professors Jordan and Burrill, for the months of June to December, 1899. (The chart is reproduced on page 7399 of record.)

"This chart shows that the Desplaines River at its mouth contains about 6,000 more bacteria per c. c. than the Illinois River, at Grafton, while the Missouri River, at West Alton, contains about 7,000 more bacteria per cubic centimeter than does the Illinois at Grafton, the Kankakee, the Big Vermilion and the Sangamon Rivers, from one to 2,000 less bacteria per cubic centimeter than the Illinois River at Grafton, while the Fox, and the Mississippi at Grafton, about four thousand fewer bacteria to the c. c. than the Illinois at Grafton. (7400.)

"As to the condition as shown by the number of bacteria, the Desplaines and the Missouri would seem to be in a less satisfactory condition, and the Fox and the Mississippi Rivers at Grafton in a slightly better condition than the Illinois at Grafton from May to December, 1899. There appears to be not any great difference in this respect as regards the condition of the Kankakee and the Sangamon Rivers, at their mouths, and the Illinois River at Grafton.

"I have prepared tables based upon the mean results of Professors Jordan and Palmer of the tributaries of the Illinois River at their mouths with the Illinois River at Grafton for the months of January to June, inclusive, 1900. (7401.)

"I have prepared a chart based on the tables just introduced. (The chart is reproduced on page 7405 of the record.)

"This chart shows that the Mississippi at Grafton and the Missouri at West Alton contained from January to June, 1900, more albuminoid ammonia and oxygen consumed than the Illinois River at Grafton, and the Desplaines, Kankakee and the Fox contained nearly the same amounts and the Big

Vermilion and the Sangamon Rivers at their mouths less amounts. Or, in other words that the Mississippi at Grafton and the Missouri at West Alton contained more undecomposed organic matter than the Illinois at Grafton; that the Kankakee and the Fox contained about the same amounts and the Big Vermilion and the Sangamon less undecomposed organic matter. The free ammonia in all the streams is higher than in the autumn of 1899, but the relative ratios is not greatly changed, and in the autumn of 1899 as in the spring of 1900 the Illinois at Grafton contained more free ammonia than its tributaries. The nitrogen as nitrites is much less in the Illinois at Grafton in 1900 than in 1899, .027 parts against .047 parts, while the amount in the Mississippi, the Missouri, the Desplaines and the Big Vermilion is about the same in the two different parts of the year.

On page 7442 of the record he further says:

"The chart just introduced shows in the first place that the Illinois River at Grafton contains much less organic impurity in May and June, 1900, than it did in the corresponding months of 1899. The nitrogen as free and albuminoid ammonia, nitrogen as nitrites and the oxygen consumed was less in these months of the year 1900 than the corresponding months of 1899. With the exception of the Big Vermilion all the tributaries to the Illinois and the Mississippi at Grafton contain more nitrogenous organic and easily exodizable matter during May and June, 1899, than did the Illinois at Grafton during the same months. It is also seen to be the same for 1900, that is during May and June of 1900, excepting the Big Vermilion all the tributaries to the Illinois and also the Mississippi at Grafton and the Missouri at West Alton contained more nitrogenous organic and easily oxidizable matter than did the Illinois at Grafton during the same period. (7442.)

On page 7445 he says:

"During May and June of 1900, the Illinois River at Grafton contained, excluding the Fox River, not only less bacteria per c. c. than any of its tributaries, less than the Mississippi at Grafton and the Missouri at West Alton, during the same months in 1900, but also contained a less number of bacteria than did any of its tributaries with one exception, the Big Vermilion, during the corresponding months of 1889. The Missouri at West Alton is shown by the chart to contain over 40,000 more bacteria per c. c. during May and June, 1900, than the Illinois at Grafton. The Illinois at Grafton containing only 8,740 per c. c.

"The tables and charts which I have offered in evidence show that the sewage of Chicago, as it enters from the sewers into the Drainage Canal undoubtedly contains a small amount of oxygen and the first action that takes place is undobutedly anaerobic action in which part of such substances like urea are decomposed, ammonia being given off. The action in the Sanitary Canal is an anaerobic action, or very similar to that which takes place in the septic tank. By this action about 20 per cent. of the organic matter as measured both by the loss in the albuminoid ammonia and by the loss in oxygen consumed is removed from the sewage. Also a certain amount of suspended matter is removed and a certain amount of suspended matter has been rendered soluble and a certain amount has been converted into gases and into simpler products.

"By this action the sewage is not only purified, but changed so that further purification will take place more easily. The next stage in the purification is the aerobic stage. Undoubtedly in the upper stretches of the river near Joliet we have both aerobic and anaerobic action taking place. Further down as at Ottawa we have principally an aerobic or nitrifying action. At about this point both in 1899 and 1900 is the zone of greatest decomposition. From this point the action,

in my opinion, is entirely anaerobic or nitrifying action continued purification going on until we come to Averyville."

"Between Averyville and Wesley City the tables and diagrams that I have made show that a large amount of organic polluted matter is added to the river. At Pekin or between Peoria and Pekin, we have also again more or less anaerobic action with aerobic action taking place. (7447.)

"The purification continues and between Pekin and Havana the action that takes place is aerobic or a nitrifying action. The aerobic purification then goes on until at Grafton, all the original organic matter which was in the sewage at Pekin has been decomposed and changed.

"The effect of emptying the sewage of Chicago into the Drainage Canal into the Desplaines River at Joliet and then into the Illinois River is to increase the amount of organic matter in the upper stretches of the river.

"The effect, however, of adding this organic matter to the upper stretches of the river is not noticed at Averyville except in the increased nitrogen contents of the river and the high chlorine and the same can be said at Grafton, at the mouth of the Illinois River. At that point the effect of the addition of the sewage to the Illinois River is seen only in the high chlorine and the nitrogen as nitrates. This nitrogen content of the river is very different from the nitrogen content of the river at or above Ottawa. It is nitrogen which has been changed over and over again from the original character in which it occurred at Joliet. How this change takes place I have tried to show in my description of the nitrogen cycle. These charts also show that the purification of the river in the two years took place exactly in the same way and also that the river at all points was purer during May, June, July and August in 1900 than in 1899. My opinion is, as has been shown by my answers to the previous questions, that I believe that the sewage of Chicago is entirely decomposed

before Grafton is reached, and that the only effect that we perceive in the river at Grafton, is the nitrogen contents and in high chlorine. The nitrogen contents and the chlorine, such as are found in the river at Grafton, are not in themselves elements dangerous in the slightest degree, to public health. They have, so far as we know, absolutely no effect upon the human system. I have studied the coli determinations as given by Professor Jordan in Streams Examinations, also his coli determinations made in 1901, and introduced in evidence in this case. I have acquainted myself with the experiments made upon the viability of the typhoid germ by Professors Jordan, Zeit and Russell. (7445.)

"Taking into consideration all the data that I have presented and all the data that I have studied regarding the Illinois River, and assuming that you mean by deleterious matters any matters that were in the sewage of Chicago that were deleterious to human health, and by infectious matter that you mean typhoid bacilli, I do not believe that they reach down the Illinois River as far as Grafton.

"My reasons in full for this answer are that in my opinion all of the deleterious substances which may have been considered to have been contained in the Chicago sewage meaning by deleterious substances not bacterial life, have been entirely decomposed and rendered absolutely harmless long before the river reaches Grafton, and that the infected matter, meaning by that typhoid bacilli, which enters into the Drainage Canal from the sewage of Chicago would not survive the passage from Chicago to Grafton. (7450.)

"All of the data that I have presented show that the Illinois River at Grafton does not contain undecomposed matter derived from the sewage of Chicago and it is my opinion that the typhoid bacilli from Chicago would not survive the journey from Chicago to Grafton, and therefore it is my opinion that the water of the Mississippi River west of the center of

the Main Channel of said river below the mouth of the Illinois River and down to the intake tower of the St. Louis water works at the Chain of Rocks, is not less valuable for drinking purposes and not more liable to carry water-borne diseases, such as typhoid fever and cholera, now than it was before the sewage from the Sanitary District of Chicago was run into the Drainage Canal. (7452.)

"I am very firmly of the opinion that the waters of Lake Peoria cannot at any time contain as much infectious and dangerous material, as the waters at Bear Trap dam, and I know absolutely of no data that would warrant any such assumption.

"Knowing the character of the Illinois River and bearing in mind the amount of sedimentation, the amount of dilution and the amount of purification that occurs between Chicago and Grafton and especially bearing in mind the time element, I do not believe that the time interval would render the Mississippi River water at all times free from liability of producing water-borne diseases from pathogenic bacteria entering the Illinois River by way of the Drainage Canal. It being my opinion that typhoid fever bacilli from Chicago entering the Illinois River do not survive the journey from Chicago to Grafton. (7454.)

"I can find no evidence that shows that the typhoid bacilli does or can pass from Chicago out into the Illinois River, thence to the Chain of Rocks and the intake tower at St. Louis.

"From all the data that I have studied, and from all the knowledge that I have been able to obtain regarding the Illinois River I find not the slightest evidence that the Illinois River, containing the mixed sewage and Canal water from the Chicago Drainage District since the opening of the Drainage Canal renders the waters of the Mississippi River below the mouth of the Illinois River less safe and wholesome than it

was before the opening of the Canal, for drinking purposes on the part of the inhabitants of Missouri.

"From various experiments that have been made it has been shown that the vitality of the typhoid bacilli is greater in pure water than in water polluted by sewage, and basing my opinion on these facts, it is my opinion that the sewage from Chicago does not favor the longevity or growth of germs from Peoria or anywhere else emptying their sewage into the Illinois River. (7456.)

"From all the tables that I have studied and the various analyses that have been made upon the waters of the Illinois river, all indicate that the zone of the greatest decomposition in both 1899 and 1900, before and after the Sanitary Canal was opened in the upper stretches of the river was in the neighborhood of Ottawa. In the lower stretches of the river there is in both years another zone of decomposition somewhere between Pekin and Havana. (7458.)

"From my knowledge of the Illinois River, flowing as it does at high water over a very large amount of territory, and the fact that the river is studded with lakes, nearly all the way from Upper Peoria to its mouth, I do not believe that even at the different stages of water of the Illinois River, the sewage from the City of Chicago, passing through the Drainage Canal into the Illinois, at different seasons of the year, would be a danger or a menace to the inhabitants of Missouri and the citizens of the City of St. Louis, using the water of the Mississippi River at the intake tower, at the Chain of Rocks.

"From the chemical and bacterial analyses introduced in evidence by Professors Long, Palmer, Burrill and Jordan, together with my study of the tables and charts that I have prepared and introduced as evidence, it is my opinion that the Mississippi and the Illinois Rivers practically contain about the same amount of impurity, while the Missouri River

contains a larger amount of impurity than either of the other two rivers named.

"It is my opinion as a sanitary expert and with a knowledge of conditions that obtain in and along the Illinois River, and from the evidence that has been submitted in this case, that such infected matter or pathogenic germs which come into the Drainage Canal from Chicago, do not reach as far down the Illinois River as the City of Grafton. (7460.)

"It is my opinion all the examinations that I have studied, as well as my own tables and charts show, that the waters of the Illinois River at Grafton are in a purer state since the opening of the Drainage Canal.

"They are certainly not less sanitary than the waters of the Mississippi River, and they are in a better sanitary condition, as shown by the bacterial and chemical analyses than the waters of the Missouri River." (7463.)

John W. Hill, hydraulic engineer, testified as follows:

"Basing an opinion upon the technical investigations that have been made of the water of the Illinois River at Grafton during the four selected months of 1899 and the four corresponding months of 1900 it does not appear that the sewage of Chicago has materially changed the conditions, and such changes as are shown would indicate from a chemical point of view an improvement in the quality of the water at Grafton, since the opening of the Drainage Canal. (7524.)

"Basing an opinion on the technical data contained in the book entitled Streams Examination which has been referred to before in my testimony, there is nothing to indicate that the danger to public health has been increased since the opening of the Drainage Canal. In making this statement I wish it understood that I do not believe that the water flowing in the Illinois River at Grafton before the opening of the Drainage Canal was fit for drinking and some other domestic uses, and my answer must be construed as showing only that the condi-

tions are no worse during the months of 1900 which I have under consideration than they were during the corresponding months of 1899 prior to the opening of the Canal.

"Taking all the data together and particularly that relating to the total oxygen consumed, and the nitrates and nitrites, I consider that the condition of the water flowing in the stream at Grafton has been improved. (7529.)

"Basing the opinion upon the technical data collected by others for the purpose of this investigation, I do not think that the sewage of Chicago in its original condition is manifested in the waters of the Illinois River at Grafton. The question of high or low water in the Missouri, at a time when there was high water in the Illinois River, would have no effect on the result at Grafton. (7530.)

"Considering the technical data already referred to in previous answers and contained in the book entitled Streams Examination and considering the relative drainage area of the Illinois River and the Mississippi River above St. Louis and of the Missouri River, I do not think that any marked effect would be felt in the combined waters of the three rivers by reason of the combined discharge of sewage and Lake Michigan water into the head waters of the Illinois River at Joliet.

"I should think that a typical bacillus would perish more quickly in the sediment of a stream than in the water above such sediment. I should not expect a typhoid organism introduced into the Illinois River, together with the sewage of Chicago and Joliet, to pass the entire length of the stream. Upon the contrary I should expect it to perish somewhere in transit and probably before it reached the City of Peoria, and the reason for this opinion is based upon the evident rate of reduction of organic matter in the river between the point of discharge into the Canal and the City of Peoria, the typhoid

bacillus like other bacteria being a part of this organic matter.

"I do not regard the settling basins at St. Louis, as they are at present constituted, a complete guaranty against infection coming from the waters of the Mississippi River.

"If upon a water shed where the water is polluted, there should be many sources of pollution and infection and typhoid fever should break out in a given community, I would look for the source of infection at the nearest possible point of pollution above the source of water intake, or above the point of water intake. (7539.)

"Basing an opinion upon the technical data in the volume entitled Streams Examination previously referred to in my testimony I should regard the quality of the water of the Illinois River at Grafton as no worse and in some respects better than the mixed waters of the Illinois, Mississippi and Missouri Rivers at the point in the Mississippi River, below Grafton as shown by the data in the tables of technical data previously offered as a part of my testimony.

"From a bacteriological point of view the water of the Illinois River at Grafton is decidely better that the water of the Mississippi River at West Alton. Considering the suspended matter the water of the Illinois River at Grafton is superior to the water of the Missouri River at West Alton. (7542.)

"The same statement may be made with reference to total solids.

"The same statement may be made with reference to the nitrates and nitrites. The degree of nitrification being shown as greater for station 21 at Grafton, at the mouth of the Illinois River than for station 32, West Alton on the Missouri River.

"The information which I have with reference to the Illi-

nois River and the quantity and quality of the stream flow, its physical characteristics and the technical data obtained from an examination of the water samples does not warrant the belief that infected matter from Chicago would be found in the Illinois River as far south as Grafton.

"If typhoid fever germs were found at the St. Louis intake, it would be wholly impossible, in my opinion, to say what city they were from. (7550.)

"In my opinion, typhoid bacilli could not be deposited on the bottom of the Illinois River and remain there for a period of five years and upwards and then be stirred up by the action of the wind, waves or steamboats, etc., and continue on their journey down to St. Louis. The Missouri, Illinois and Mississippi Rivers were not safe waters for drinking and domestic purposes prior to the opening of the Canal. (7557.)

"I do not regard any river that receives the sewage of rural and urban populations, as a safe drinking water without mechanical treatment of some kind. Basing an opinion upon the technical data before me, applicable to this question, upon the whole, the condition of the water of the Illinois River at Grafton appears to be improved by the opening of the Drainage Canal and is not less sanitary than the waters of the Missouri and Mississippi Rivers. (7553.)

"There is no evidence before me showing that any such changes occurred in the quality of the water as to render it less desirable for potable purposes, or more deleterious to health than prior to the opening of the Canal." (7554.)

Effect of the Opening of the Drainage Canal as Shown by the Lay Testimony.

When the scientific evidence is conflicting, uncertain and doubtful, the physical facts and practical evidence are the controlling factors in arriving at a conclusion in a case like this.

If the determination of the case should rest upon the scien-

tific evidence alone, as shown by the record, the complainant could not prevail as it has failed to make out a case by "satisfactory and determinate evidence."

The Court in passing on the demurrer in this case laid down the following rule:

"We fully agree with the contention of defendants' counsel that it is settled that an injunction to restrain a nuisance will issue only in cases where the fact of nuisance is made out upon determinate and satisfactory evidence; that if the evidence be conflicting, and the injury be doubtful, that conflict and doubt will be a ground for withholding an injunction; and that, where interposition by injunction is sought, to restrain that which it is apprehended will create a nuisance of which its complainant may complain, the proofs must show such a state of facts as will manifest the danger to be real and immediate."

Missouri v. *Illinois & Chicago Dist.*, 180 U. S., 248.

In Volume 2 of Story's Equity Jurisprudence, Section 924, it is said:

"But in all cases of this sort a Court of Equity will grant the injunction to restrain a public nuisance only in cases where the fact is clearly made out upon determinate evidence. For if the evidence be conflicting and the injury to the public doubtful, that alone will constitute a ground for withholding this extraordinary interposition; and, indeed, the same doctrine is equally applicable to cases of private nuisance."

In Wood on Nuisances, Vol. 1, p. 732, Section 539, it is said:

"The injury must be such as is apparent to the eye in its ordinary condition, and must be clearly traceable to the nuisance charged. If there is a reasonable doubt as to the cause of the injury the benefit of the doubt will be given to the defendant if his trade is a lawful one and the injury is not the

necessary and natural consequence of the act, as in all actions of this nature the burden of proof is upon the plaintiff."

Tested by the above rule, has the complainant shown by "satisfactory and determinate evidence" that the sewage discharged from the sewers of Chicago into the "Drainage Canal" has materially increased the pollution of the water supply at the intake of the St. Louis water works at St. Louis, as measured by the scientific evidence solely and alone? The scientific (the only) evidence introduced by the complainant itself, without considering that of the defendant, is doubtful, uncertain and conflicting and even upon that evidence alone complainant has failed to make such a case as would warrant the Court in issuing the injunction asked in this case. When the Court comes to consider all of the scientific evidence, it will be seen that it is conflicting, uncertain and doubtful, yet it very largely preponderates in favor of the defendants.

In case of nuisance the rule announced by the Courts is that scientific evidence ought to be considered *secondary* only as to the evidence as to the facts.

In *Newark Aqueduct Board* v. *City of Passaic*, 18 Atl. Rep., 106; 45 N. J. Eq. Rep., 393, the Court say:

"In *Goldsmid* v. *Commissioners*, L. R., 1 Ch., 349, Lord Justice Turner, referring to the testimony of scientific experts in a case of nuisance said: 'Speaking with all possible respect to the scientific gentlemen who have given their evidence, and as to whom it is but just to say that they have dealt with the case most ably and most impartially, I think that in cases of this nature much more weight is due to the facts which are proved than to conclusions drawn from scientific investigations. The conclusions to be drawn from scientific investigations are, no doubt, in such cases, of great value, in aid or in explanation and qualification of the facts which are proved, but in my judgment it is upon the facts which are proved, and not upon such conclusions, the Court ought

in these cases mainly to rely. * * * In my view of this case, therefore, the scientific evidence ought to be considered as secondary only to the evidence as to the facts.'"

The defendants introduced in evidence the testimony of a large number of witnesses who have had a practical knowledge of the Illinois River for years, both before and after the opening of the Drainage Canal. These witnesses consist of fishermen, boatmen, engineers, physicians, fish commissioners, both for the State of Illinois and for the United States, lock tenders, and others.

The witnesses spoke from actual and practical knowledge of the character, appearance, and sanitary condition of the water of the Illinois River at different places along the same. A large number of these witnesses used the water both before and after the opening of the Canal. The Illinois River for the purposes of this trial, so far as the defendants are concerned, was divided into two sections, that is to say, the upper section being from Chicago, by way of the Drainage Canal, the Desplaines River and the Illinois River, to Peoria. The lower section, being from Peoria to Grafton, at which point, the Illinois River empties into the Mississippi River. The distance from Chicago to Peoria by the Drainage Canal and rivers, is 160 miles. The distance from Peoria to Grafton by the Illinois River is 160 miles.

Testimony was taken by the defendants, commencing at Morris, Illinois, a distance of 60 miles from Chicago.

Morris.

H. M. Ferguson, a physician who resides at Morris, Illinois, testifies as follows:

"Before the opening of the Canal the Illinois River here was bad. It was murky, ill-smelling, dead and rotten. We could smell it here in town, about a quarter of a mile away. There was a scum on the river and plant life.

"This plant was like a clover leaf.

"The water in the winter time was very bad. Since the opening of the Canal the condition has been better. The water is clearer, less odor and less solids in suspension, and you can see the bottom more. There is a better current. I consider the water since the opening of the Canal decidely better than before. Took samples of water for the State Board of Health, in 1899 and 1900, under the instructions of Dr. Long and Mr. Harman." (3863.)

L. D. Ray, testifies as follows:

"I have lived in Morris, Illinois, since 1855. Have been a member of the legislature, in both houses, and Lieutenant-Governor four years. Mazon Creek drains the northern part of Livingston and the southern part of Grundy Counties.

"The DuPage River is quite extensive, with its source up in Wisconsin. In dry seasons before the opening of the Canal the condition of the Illinois River was not good. There have been times when you could be in town and get an odor here which I suppose is from the river. In winter when we were driving on the river, when we came to an air hole, it would be vile.

"Since the opening of the Canal the condition of the water has been improved. The Illinois River at this point is a considerable body of water at flood season. Nettle Creek runs up through the northwestern part of our country. It empties into the river just below the town here. (3878-9.)

Several other witnesses were examined who resided at Morris, Illinois, whose testimony is to the same effect as the above witnesses.

Marseilles.

Testimony was also taken at Marseilles, Illinois, which is about 70 miles distant from Chicago. Mr. R. H. Adams, Vice-President of the Marseilles Mfg. Co., testifies as follows:

"Am Vice-President of the Marseilles Mfg. Co. We manufacture agricultural machinery .Have lived here 36 years. We employ from 150 to 250 men. Prior to the opening of the Canal, the Illinois River water was very impure, the water of the stream rising from swamps largely. The water was in a very impure condition and before the sewage of Chicago was turned into the I. & M. Canal, we didn't care to bathe in it for fear of getting mud itch. It was quite a dark color and there was a good deal at times of a kind of dense formation would come down and the water was not pure enough so that you could see any depth in it.

"When the sewage of Chicago was turned into the I. & M. Canal there was a bad odor to the Illinois River. If the water was not high, you would see a kind of oily substance on the surface. Just before the opening of the Drainage Canal, the condition was bad. It had a bad smell and was so intensely filthy that the water from the wheels would saturate the men's clothes and even their systems so that when they would go away from the shops sometimes for days if you went near them you would smell what we called the shop smell of the water. It got very strong. Since the opening of the Canal the water has improved very much. During the past year since they have let in some water. I don't know that there has hardly been a time we have had any of that smell. In our head raises, where it used to be so dense you couldn't see any depth, there are often times when you can see two or three feet down clearly. The opening of the Drainage Canal has effected a very decided improvement on the Illinois River in every way, in health and everything. I think. Prior to the opening of the Canal in some parts of the town we used to have quite a little malarial fever, ague and such things as that. Of late, I have not heard anything of that." (3835.)

James Bruce, grain merchant, testified as follows:

"Have lived in Marseilles eight years and am a grain mer-

chant. Have been acquainted with the Illinois River all my life. Prior to the opening of the Canal during the summer months, the river was very low. It showed the effect of the drainage of Chicago and the gases from the river were very strong. There were places in the river where it showed stagnant water covered with green slime. To-day I think that has all disappeared with the extra head of water and very little gas is found. There has been a general improvement. The river is fairly clean so far as I can see—no stagnant water, and the water has a good flow. At Joliet, my old home, especially between Lockport and Joliet, the operation of the gas showed its effect on the houses there. If you painted a house, inside of a year, it would turn black like my father's place there. Since the Canal was opened, we have no such trouble. The game fish are returning up here. (3827.)

This evidence was supported by other witnesses at Marseilles, Illinois.

Ottawa.

Testimony was taken at Ottawa, Illinois, a distance of 81 miles from Chicago.

Daniel C. Woods, testified as follows:

"Am at present clerk in the Clifton Hotel at Ottawa. I have done a little work for the Government in the way of reading the guage on the river for the U. S. Geological Survey. Have been acquainted with the Illinois River forty years. The condition of the Illinois River prior to 1900 in the early days away back, was not so bad. Afterwards it became fouler and fouler until it was very foul. I was engineer on the Chicago & R. I. railroad and that road abandoned their tanks in the station at Joliet and built a coal chute and tanks out about a mile and a half from the station. They also put in filters, but even using the filter the water was so foul that when it was running from the train into the tank, if the wind happened to blow towards the engine it was sickening to the en-

gineer and steam escaping from the gauge cocks or boiler head would sicken you with the foul smell. At Ottawa the smell could be noticed three miles before you reached the town, governed by the direction of the wind.

"The water improved as it diffused itself in traveling in the river. Since the opening of the Canal there is all the difference in the world. It is now what you would say a clear stream. I see the river every day twice a day at the C., B. & Q. bridge where I go to get my gauges. There is not a particle of slime now any more than any stream you would find in the country that was a clear nice river. The effect of the opening of the canal has been to change the river from a vile stream—a stream that you would know at one glance was vile—that you wouldn't eat a fish out of the river—to a nice clear stream that you would class with any other stream. In fact they are catching lake fish right here at Ottawa. (3805-7.)

Henry Mayo, testified as follows:

"Have lived in Ottawa since 1854. In 1887, was at the head of the executive and judiciary committee for the Illinois Valley Association which was an organization of people looking into the question of turning the sewage of Chicago into the valley of the Illinois River. I was associate counsel for the special commission appointed by the Governor until the water was turned into the channel of the Desplaines River."

"For five years prior to January, 1900, the upper level of the Illinois and Michigan Canal itself supplied the water from the pumping works at Bridgeport. The water lifted by the pumping works into the Canal was very largely sewage from the south branch of the Chicago River. It was almost thick. The average amount of water lifted by the pumps at Bridgeport, I think was about 45,000 cubic feet per minute; sometimes more and sometimes perhaps a little less, but the average amount would be about 45,000 cubic feet of water per

minute, about 12,000 cubic feet of water per minute of that amount was required for the purposes of navigation in the Illinois and Michigan Canal. The balance, the excess drawn by the pumping works at Bridgeport was spilled into the Desplaines River where the Canal came to the river, and came down through the Desplaines River from the upper basin of the Canal and thence into the Illinois River. The condition of the Desplaines River at Joliet and down to the Illinois River, while this matter was discharged into it was very offensive. There was a very strong odor from the dams at Joliet, the water was very dark in color and very thoroughly impregnated with sewage. The Desplaines River entered the Illinois River just above Wilmington and forms the Illinois, by its junction with the Kankakee River.

"The Illinois River where it is formed by the junction of these two rivers, prior to the opening of the Drainage Canal was very much impregnated with the sewage that was taken out of the south branch of the Chicago River by the pumping works at Bridgeport, so much so that the water had a very strong smell—very offensive and was in a bad unhealthy condition. In the vicinity of Ottawa there was a vegetable growth on the water in warm weather and a scum formed upon it. It had a very strong oder, but not so much in the summer as in the winter when the river was frozen over. I live on the south side of the river and cross it two or three times a day and know what I am talking about. I have seen times when it disturbed my meals very much to cross the river before the water was turned in, when the ice was breaking around the piers. The odor was generally most offensive in the winter.

"Since the opening of the Canal the Desplaines River at Joliet and down to Wilmington, and the Illinois River from Wilmington to Ottawa, have been, in my judgment, very much improved. The condition of the water both winter and sum-

mer has been very much better than it was before. It has not an odor in winter that I have perceived. It has very much improved in appearance as well. At the Illinois bridge, which is just below the mouth of the Illinois River, there passed 150,000 cubic feet of water per minute and the water in extreme low stage was very offensive, because perhaps one part in six was sewage that came through the pumping works at Bridgeport. That condition has improved vastly since the opening of the Canal." (3774-8.)

La Salle.

The next testimony was taken at La Salle, a distance of 100 miles from Chicago.

John Grubb, testified as follows:

"Am a fisherman.

"Before the opening of the Canal the Illinois River was kind of stagnated along the shores and slimy stuff would be running along the shores and it would stink. People could not live along there. They would get malarial ague and one thing and another that way and the fish would not be any good along the shore. The only effect I see of the opening of the Canal is that fishing has been a little bit better and the fish will live longer in the water and furthermore when I go over there in the spring or fall, I generally take a drink of it. I have not heard of any fishermen who drank the water being made sick on it. There is more fresh water now. Fish live in live boxes and before the opening of the Canal they would not live until the next day hardly.

"They live now for a week. Before the opening of the Canal the fish we used to catch under the ice would taste tarry and gassy. You couldn't eat them. Now the fish have been tasting pretty good. I have drank the water in the river since the opening of the Canal eight or ten times a day in the spring or in the fall. It has had no effect on me. It made me

feel like drinking more. Since the opening of the Canal I think the river is better for my part and for all the fishermen. They are all catching lots of good fish up there. They catch cat fish, lake perch, a few white fish and all kinds of game fish. There were more pickerel and black bass around this spring than there have been for a good many years."

Charles Rimmele, testified as follows:

"Am in the boating business. Run a small pleasure launch.

"My father and I run it together. Before the opening of the Canal the water had a strong smell to it, full of moss. The water was low, pretty near dead water. Since the opening of the Canal the water has been a great deal clearer, no moss, better fishing and no smell. There are more fish than we ever had, and more water. We have got a good deal better current." (3749.)

W. E. Stafford, testified as follows:

"Have lived at La Salle seven years. Am manager of the Postal Telegraph, also run a boat with Mr. Masterman—the Steamer Creve Coeur. Before the opening of the Canal the river did not have the clear appearance that it has had since. It had more grass, gas and stuff of that kind. Sometimes there was an odor. Since the opening of the Canal we don't discover it so much. The water has more of the blue cast now. It looks clearer, a great deal. The opening of the Canal has raised the water some. The color is clearer than it used to be and the current has increased. We all drink the water on the boat. It never made me sick. Have not had typhoid fever." (3752.)

Dr. Floyd Clendennon, testified as follows:

"Have been practicing medicine in La Salle about thirty years. I think the public health in the City of La Salle since the opening of the Canal has been improved. There is very little typhoid fever in the city now.

"The condition of the Illinois River before the opening of

the Canal was bad. It is now decidedly better. The water is purer. The drinking water used here is based on the water from the Illinois River, the I. & M. Canal and from some springs and some artesian water. It is a mixture. That water is largely drank by the people. There is very little typhoid fever among the people. I am surprised that there is not more of it, some of the water comes out of the Canal and swamps. I had less typhoid to treat last year than I ever had before." (3758.)

Walter A. Panneck, testified as follows:

"Am an attorney, am Mayor of La Salle * * * condition of public health for past three years has been very good Our water supply comes from Smith's Springs, and Spring Dell Springs and water that comes from I. & M. Canal that is driven through gravel and sand to what is known as the intake, three and one-quarter miles east of La Salle and from there it comes by natural gravity into the pumping station and is from there sent out to the city. The connection between this intake and the I. & M. Canal is a kind of a small Canal with a sand and gravel bottom to it, and the water coming from the Canal just simply flows over the sand and gravel into the lake. It does not flow through it; it travels over it. The water used in the city is made up of a mixture of the spring waters and the water of the I. & M. Canal. This water is used for domestic purposes. The people drink the water. From that water there has not been a case of typhoid fever since I went into office. Before opening of Canal during dry season the Illinois River was very low and stagnant; generally a green scum; practically no flow and the odor was very strong. Since opening of canal it has improved considerably. There is no nauseous smell emanating from the river and there is considerable current to it now. It doesn't get as low as it frequently did and the water is clearer. The Little Vermilion River enters the Illinois River at this point.

Cross-Examination.

"At the present time we must be using, I would judge, about 500,000 gallons of water per 24 hours out of the I & M. Canal. We are using considerable of that water at the present time. The water comes out of the I. & M. Canal through a 12 inch pipe and flows on the surface of the ground immediately south of the embankment, upon the south of the Canal. We are 100 miles from Chicago. We have never spent a dollar upon graveling or filtering that water. The water that comes into the lake through the valve from the I. & M. Canal while it is in the Canal at this point appeared muddy, dark. The water from the I. & M. Canal mixed with spring water is all right. It is common, ordinary Canal water." (3725-31.)

Mr. F. L. Masterman, testified as follows:

"Have lived in La Salle off and on for thirty years. Am agent for the Adams Express Co. Have been on the river a great deal running steam boats. Run the Creve Coeur with Mr. Stafford. Since the opening of the Canal the water is 18 to 24 inches higher. The quality of water in the upper river, where we do the most of our boating is a great deal better—nice clear running water, where it used to be stagnant. There was a natural swamp odor to it. There is no chance for odor on the water now. There is probably in the upper river from four to five mile current. Never experienced any deleterious effects from drinking the water." (3753-4.)

The above evidence taken at La Salle is further supported by other witnesses.

Henry.

Testimony was taken at Henry, Illinois, a distance of 123 miles from Chicago and 33 miles from Peoria.

Clyde Banter, testified as follows:

"Live here in Henry. Have been fishing here for last nine years. I fished about three miles below Copperas Creek and clear to Spring Valley. (Spring Valley is north or towards Chicago from Henry.) At this place before the opening of the Canal the nets took the slime up a great deal and the water used to be green and scummy like. I don't think it was as pure as it is now by no means. In the winter time in low water when the river froze the water would get gassy, tarry and make the fish taste so people couldn't eat them. There was no market for tthem; fish couldn't stay in the back water lakes in low water before the drainage was in. Since the Drainage Canal was opened the first year the water wasn't as good as it is now; now the fish lives good and everything; we wouldn't ask for any better water at all, and the boilers on the boats don't foam or nothing. Four years ago we couldn't keep steam in the boiler for foaming water; she would foam over. I have run a boat operated by steam on the Illinois River five years this July 1st. The water foamed in the boilers prior to opening of Canal below Peoria, in the summer time. First year after canal was opened she foamed a little bit, but she don't foam any more. Since the opening of the Canal the water from Peoria to Spring Valley is all right for the boilers; no complaint at all; for the last two years there ain't been no foaming done in the boilers at all. I am acquainted with nearly all of the fishermen between here and Copperas Creek. I don't think there is anybody that I know of amongst the fishermen that had the typhoid fever in the last three years. I know, by golly, I ain't had the chills for a long while." (3466-9.)

B. F. Forrest, testified as follows:

"Reside in Henry. Have been a physician for 20 years and practiced in Henry and vicinity about 13 years. My practice extends in a general way as far north as Hennepin and as far south as Lacon. I was mayor of the city from 1892 to 1894 and 1898 to 1900. We have no system of public sewers. As a rule the household sewage is thrown out. Some people haul it away in barrels but the most of it is thrown on the top of the ground in back yards and alleys, a large portion of it, and privies. There are no cess-pools here. The population is about 1,700. There are two cases of typhoid here at present. One of the patients has been away from home, visiting in Indiana and was taken down with this malady at once after returning, and has had it for three weeks. I don't know what to attribute the other case to. I enquired particularly as to any cause of infection and learned that they have been using cistern water only. Since the opening of the Canal there has been no deaths from typhoid. The dejecta of the two patients is disinfected with carbolic acid and lime and emptied into the vault. I have fished a good deal on the river with pole and line and also backed a seining outfit knowing what they were doing. At this point before the opening of the Canal in times of high water the Illinois River was in good condition—that is the condition of the water was fairly good. In conditions of low water the water was very bad, polluted. After the river would become frozen over, there was a break in the column of ice at the dam; at times the gases that would arise from that break in the dam where it didn't freeze over would become very bad; at times so much so that it was offensive. The effect was to kill the fish. The fish were tainted and unfit for food.

"Since the opening of the Canal the water apparently has been better; there has been an absence of this stench and I haven't noticed it as much, not near as much. As to the fish I have heard no complaint. I have known the fishermen

have taken them all this season and used them for food." (3473-5.)

Fred Bauter, testified as follows:

"Live at Henry. Have been fisherman on the Illinois River between 9 and 10 years. Run a steam tug or boat in my fishing on the river. Since the opening of the Canal the conditions above Peoria and up to Henry has been good; the water is more pure; keeps cooler, fish keep a good deal better and there is no time in the water that you can't drink it. I never notice any smell. Am pretty well acquainted with the fishermen. Since opening of the Canal I have not known of any typhoid fever among them." (3492.)

To the same effect is the testimony of other witnesses, all of whom reside at Henry, Illinois.

Testimony was taken at Lacon, Illinois. Lacon is about 135 miles from Chicago and 25 miles from Peoria.

William Mangle, testified as follows:

"Am fisherman. Have been a fisherman on the Illinois about 18 or 20 years. Fish between Henry and Chillicothe all the time.

"Before the opening of the Canal the river at this point was pretty low. It had a kind of moss or green stuff floating in it in low water. It would be probably a foot deep along the shore. No smell in summer to amount to anything. The water was pretty bad under the ice at low stage. It was gassy. When you cut a hole in the ice a kind of gas or tar smell came out. The fish would taste just like it smelled. A good many died under the ice. Fish didn't live long in hot weather in live boxes. Since the opening of the Canal there hasn't been much of the green plant in the water. No smell under the ice and the water is better a good deal, and the fish live better. We drink the water in cold weather. Fishermen in this vicinity haven't had typhoid fever that I know of since the opening of the Canal." (3436.)

Will Read testified as follows:

"Am fisherman. Have also fired on steamboats. Have been occupied as a fireman on the Illinois River pretty much every summer more or less. I have traveled from Peoria to La Salle and from Peoria to St. Louis on the Cherokee.

* * * * *

"Above Peoria, since the opening of the Canal the water has been first rate for steam purposes. I haven't had no foaming; every time I was firing I have seen none of it.

"Since the opening of the Canal I didn't find any odor or smell when the river was frozen over. I haven't seen any dead fish in the water. Before the opening of the Canal the fish did not live very good in live boxes; now I could hold them four and five days. There hasn't been any considerable amount of this green plant in the river. The fishermen upon the Illinois River in this vicinity do not have typhoid fever that I know of." (3445-6.)

Henry Stoehrs testified as follows:

"Reside at Lacon. Am engineer at the woolen mills. Have held that position for 20 years. For 12 years have obtained water from the Illinois River for my boilers. Before opening of Canal water used to be very slimy, scummy, muddy. It didn't act very good in the boilers. It foamed the boilers and we would have to blow them off pretty often. There was a smell to the steam when we blew them off.

"The stuff that came out when we blew them off was a kind of a muddy scum, with an awful smell to it. Since the opening of the Canal it is better. I don't find that scum in them at all and haven't. The water foams very little in the boilers. There is no odor to the steam now. The water that comes off when I blow off the boilers now is in very good order; there is very little mud and very little scale."

Chillicothe.

Chillicothe is about 145 miles from Chicago and about 20 miles above Peoria.

Testimony of 13 witnesses was taken at his point.

Martin Truitt testified as follows:

"Live in Chillicothe. Have been a fisherman on the Illinois River for the last 25 years. Have fished between Chillicothe and Peoria and Chillicothe and Lacon. Before the opening of the Canal the water of the river was pretty bad and there used to be green stuff here that you could hardly row a skiff through and in winter time if you chopped a hole in the ice you would have to get away from it on account of the rotten gas coming out. The fish would die. Since the Canal has been opened it hasn't been that way. I never saw it purer in my life. The fish live better in live boxes, too, since that. The fishermen, since the opening of the Canal have not had typhoid fever.

Cross-examination:

"I live in a cabin boat. There is more current in the river now since the Canal was opened.

"Before the Canal was opened there wasn't enough current to float the green stuff off the river. There ain't so much greasy, oily substance on the water since the opening of the Canal." (3418.)

E. N. Nelson testified as follows:

"Live at Chillicothe.

"Have been fisherman off and on for 20 years. Have fished between Lacon and Peoria. Before the opening of the Canal the water in the Illinois River got very foul in low stage. In July and August the water would look green. It smelled foul and bad, especially when it was stirred up by a boat or anything. In winter when it froze up it would get a kind of gassy, tarry smell. If you cut a hole in the ice

you could hardly stand over it. The fish were unmarketable at that time of the year when the river was frozen over. You could hardly stay in the house where they were cooking them and you couldn't eat them at all. They would die in the live boxes in a very short time. Since the opening of the Canal the water has been very good in my estimation. I haven't noticed any smell and last winter I kept fish in live boxes for two months and a half." (3422.)

"I haven't known of a fisherman having typhoid. I haven't known of but one case in Chillicothe in years and that wasn't a fisherman or riverman.

Cross-examination:

"The river passing Chillicothe flows through Lake Peoria and on past Peoria. Lake Peoria is nothing more than a wide space in the river. There used to be a good deal of scum on the river. I haven't seen any on the river since the Canal opened, only in the backwater at times.

"I haven't seen any greasy, oily substance on the surface of the water. Before the Canal was opened the water was sluggish and had hardly any current at all. Since the Canal is opened, the current is a good deal swifter.

"When I say the water is better I say that from my experience of the water, it is colder and better looking and a person can drink it in a pinch now, and they couldn't at this time of the year before. I have drank it this season and last season both, when I would be on the river." (3423-5.)

Upper Peoria.

Edward N. Woodruff testified as follows:

"Am mayor of Peoria and dealer in natural ice. We have a capacity of 26,000 tons, divided into three locations along the river.

"We get our ice from Peoria Lake—a widening of the

Illinois River immediately above Peoria. I have been in the ice business about 22 years. The water of the Illinois River as compared to its condition prior to the opening of the Canal is better than it was. The water is clearer and in better condition in every way. Before the opening of the Canal we were hunting for other locations for ice cutting purposes.

"This was due to the natural prejudice of the people to begin with. In winter when the river was covered with heavy ice there was always more or less odor to the water. We have had times when there have been a lot of dead fish along the rivers. Since the opening of the Canal I haven't observed that odor under the ice.

"In my opinion, as an ice man, the water is better beyond question since the opening of the Canal. The only objection that we have had to the ice is from the soot that grows on the top and in soft weather gets into the ice and freezes there.

"The water today is much better in my opinion than it was prior to the opening of the Canal.

"There are three dealers who sell ice in the city and two St. Louis parties who cut out or harvest ice above us. They are the Muckerman Ice & Coal Company, I think is the style of one firm, and G. H. Donellaid & Company, I think are the others. They took ice from Peoria Lake last winter and I don't know how many winters before; a number of winters —eight or ten or twelve.

"Q. To what extent was their cutting and taking of ice from this place, if you know?

"A. Combined, 12,000 to 14,000 tons.

"Q. Each season, each winter?

"A. Well, probably every winter they didn't take the ice out; but they held it for reserve.

"Q. What would they do with this ice?

"A. Ship it away.

"Q. Do you know what points it was shipped?

"A. I have no knowledge of their billing, except I presume it would all go to St. Louis.

"Q. Did you learn from either of these firms, or the members of the firms, what they were doing with the ice that they cut from this lake?

"A. I have had no conversation with either one of the concerns for possibly a year; but I have been told by both of them that they were making shipments into St. Louis." (3533-7.)

Chas. F. Hixson testified as follows:

"Reside at Peoria. Run a summer resort at Shady Beach. Shady Beach is about three miles and a half above Main street. We are right at the Narrows. The condition of river above the Narrows before the opening of the Canal in the summer time when the water was very low, the water became very foul and had a very bad odor to it, and there would come a very heavy green scum through the months of July and August particularly; a man get up in the morning there at 4 o'clock or daylight, the odor that come from the river was something fearful. In winter time when river was froze over fish were not fit to eat; tasted tarry and gassy. Lots of them would die. When ice broke up in spring you would see thousands and millions of dead fish floating in the river. Since the Canal was opened it has been very much better; we have a higher stage of water. The water has been purer to the naked eye, and clearer; and we haven't that odor coming from the river that we had prior. We have had no trouble in regard to the fish since." (3557.)

Robert R. Martin testified as follows:

"Have been acquainted with the Illinois River for the last 15 or 16 years. I have worked along side of it. I have

pumped it into the city mains and have been quite a fisherman.

"Prior to the opening of the Canal in the winter time when the river would be frozen over here, the fish caught above Peoria would have a tarry, gassy taste—so much so that they were not fit to eat in the winter after the ice was frozen over for a short time. This winter we have had fish once or twice a week at our house and they have not that taste now. We relish the fish as much in winter as we do in summer. The water is clear now; before the opening of the Canal it had an odor to it. Its condition is a great deal better now. I haven't observed any odor. I think the effect of the Drainage Canal has been to give us a better river—better water." (3551-2.)

Pekin.

Pekin is situated 175 miles below Chicago and about 10 miles below the City of Peoria. Testimony was here taken as to the amount of pollution entering the river from distilleries, cattle sheds, etc.

Among other witnesses Harrry Taylor testified as follows: "Reside at Pekin, am a fisherman and have been since 1895. I have fished from Lake Depew, 12 miles above Hennepin, to LaGrange dam. I have fished all the way from here to Peoria. The water is more pure and clear now above Peoria than it was before the opening of the Canal.

"Before the opening of the Canal the water above Peoria was good water. Since the opening of the Canal it is good water yet, but it is better. The water in the river below Peoria before the opening of the Canal was rotten. It was slimy and the slime got on our nets. At Pekin it was just the same as it was below Peoria. There was a slime to the water. Since the opening of the Canal it has been more pure below Peoria. At Pekin the slime forms but not so bad as it

was before. Since the opening of the Canal the slime decreases as it goes down the river from here.

Cross-examination by Mr. Jeffries:

"The current is more stronger now than it was before it was opened. I don't believe there is a mile. There is some better current throughout the year. The water is clearer now than it was before the Canal was opened, above and below Peoria. Above Peoria it is blue, like the water of Lake Michigan. It contains deleterious matter below Peoria, caused by those sugar houses and one thing and another dumps their offall into it. I don't know whether the sewage of Chicago gets in the river above Peoria.

"I have never seen any effect of the Chicago sewage in the water. Because I have never seen it, I don't think it hurts the water." (3368-70.)

J. C. Losch testified as follows:

"I run a little boat of my own here; have done so for 12 or 15 years, the Steamer Olive A. Before the opening of the Canal in summer time the river was in bad condition, the water being foul. The foulness manifested itself by smelling and in killing the fish.

"I have seen them between here and the locks that my steamboat wouldn't have carried them, laying on the shore, killed probably the night before, that would be about 10 or 15 tons. That was about 1889 or 1891 before I bought my big boat. The water has always been better above Peoria than it has been below. Since the opening of the Canal, its effect on the waters has been to make them better. They seem to be purer. There don't seem to be as much smell nor look as bad. I haven't seen any dead fish to the extent I have saw before. There is some smell. It isn't so bad as that which existed before the opening of the Canal. Years ago, every time we went from here to Peoria, every two or three trips, we had to blow out our boilers. We don't have to do that

now. The boiler would foam and raise up with the filth and gas, between here and Peoria.

"As you go away from Peoria towards Grafton the water gets better. I have seen islands of manure in the Illinois river. I have struck them big enough that if I had hit them fair, they would take me down the river, with the little boat.

"Those that I have reference to come from Peoria. Right here at Pekin I had clearing out the distilleries here; the manure would be five or six feet deep and covered probably an acre that I tore out for them, they paid me $25 for tearing it out. That is the only place I have had to clean it out. The Peoria distilleries paid me for taking out of the Canal above Spring Lake Canal, and the still house here and the Peoria parties paid me for taking it out of the Canal. This manure floated down from Peoria and got into the Canal and stopped it up." (3371-2-3.)

Havana.

Havana is 199 miles from Chicago and about 120 miles from the mouth of the Illinois River. Nine witnesses were examined at this point, including the postmaster, several physicians, fishermen, the mayor, etc.

Dr. C. W. Morrill testified as follows:

"Have lived at Havana ten years next January. Am a physican and surgeon. Before the opening of the Canal we had very low water. It was a filthy bank all along, scum and filth all along the banks, a good deal of odor to it so you could smell it clear up town sometimes. There used to be cakes of filth that came down from Peoria. There was one at the bridge that they had to dynamite out. There was a large island came here one time and lodged at the bridge and they tried to blow it out. There was a green scum here every summer. The opening of the Canal has made more current.

The water has not been so low during the summer. The water looks purer and cleaner and the banks have been much better and there is no stench as there was before. In times of sudden freshet, before the opening of the Canal, the river would be cleared out and there was less malaria in those seasons when we had high water and less typhoid-malaria. We have had very little here since there has been high water here. Since the opening of the Canal I haven't seen any real typhoid here.

L. A. Everest testified as follows:

"Have lived in Havana 30 years. Have been a fisherman all my life. Before the opening of the Canal the water got very low during this season of the year (July) and got very filthy. During the season the water seemed to be more filthy. During the season when it would be froze up, it would smell bad. In the summer there was scum on it, a green scum. It would kill the fish in the winter time. After the river would be frozen up for some time the fish would have to go into the spring water or they would die. They would get weak, they would swim along the edge of the river and people would pull them out with gigs or forks or something. I have seen them condemned in the St. Louis and New York markets. If you cut a hole in the ice there would be an awful smell and the water would be very filthy. There were what is known as Peoria islands floating down the river. They were composed of manure. I have seen them all the way from this place to Peoria, they would vary in size all the way from two or three feet to 50 feet.

"I have seen them here at Havana. I saw a large one lodged against the bridge here that I know was blasted loose. Since the opening of the Canal the nets last longer. The water is more cool. This slime or stuff that collects on the nets comes from the stills at Pekin and the glucose factory I suppose. It is a slimy substance and will stick to

anything it touches. It flows in small pieces but will collect in large quantities on anything it touches. We call it slur-gut among the fishermen. We had it before the opening of the Canal. The nets are cleaned from the effects of the slur-gut by shaking them and taking them to the bank and whipping them with sticks. It is a kind of white color. I fish between here and Kingston.

"I find that substance on my nets up that far. There is not much difference as to the quantity we find now as compared with the quantity found before the opening of the Canal. The opening of the Canal has made the water higher and the water has been cooler and purer and not much smell to it. In the fall of the year as the water begins to get cooler, it is stronger and there is more filth near Peoria than there is near this point. The slur-gut can scarcely be noticed in summer. It don't have a tendency to float in the warm weather." (3298.)

Beardstown.

This testimony was taken July 20, 1903. Eight witnesses were examined at this point. The distance is about 230 miles from Chicago and about 90 miles from Grafton.

L. W. Goodell's testimony shows the conditions at this point. He testified:

"Live in Beardstown. Am in wholesale and retail ice and fish business. Have been in the ice business since 1887 and in fish business about seven years. We buy fish from fishermen and run a seine also. My partner, George Swan, engages in the seining.

"Prior to the opening of the Canal, the water would get pretty low at times. The current was quite sluggish and the water somewhat riley—dirty looking, not very clear looking. I have noticed a green growth—a sort of small vegetable

with two or three leaves, a little short root that would form in large masses over the surface of the water. I don't recall whether there was any odor to it in the summer time. I have noticed it in the winter time when there were holes cut in the ice. There have been times when a great many fish died in the winter time, when there was ice on the water. I don't know exactly what I attributed this smell to, except the sewage from Peoria and Pekin. I think it was that partly. It is 80 miles to Pekin and 90 miles to Peoria and 50 or 60 miles to Copperas Creek dam. Before the opening of the Canal we cut the ice from the waters of Muscoopin Bay, from the arms that project off the river above the C., B. & Q. bridge. That water is derived both from the Illinois River and from surface water that drains into the bay at the north end of it.

"As I recollect it, it was at least two winters that the fishermen complained largely of the fish dying and several times we have noticed an odor coming from the water under the ice, prior to the opening of the Canal. Since the opening I haven't noticed this green growth in the water. I have cut ice and put it up since the opening. I didn't detect any odor from the water during the last three years and the fish did not die under the ice in the last three years to my knowledge. I haven't noticed any difference in the ice cut in the last three years. The water looks clearer now than it did before." (3260-2.)

Dr. H. Eberhardt testified as follows:

"Live in Beardstown. Am a physician. Have been practicing 36 years. Am a health officer.

"Am acquainted with the Illinois River within a radius of ten or fifteen miles above and below Beardstown. Before the opening of the Canal, the river during low stage was often covered with a vegetable growth, a sort of fungus, grass and also a scum. The current during low stage of water

was very sluggish. Since the opening of the Canal so far as external appearances go, the water has had a better appearance, is clearer and it has been devoid of that vegetation which was observed before. I have observed no cases of typhoid fever before or since the opening of the Canal. I do not know of any people having died of typhoid fever in the last four or five years in Beardstown. I don't know of any typhoid fever existing in this territory now, or within the last two or three years.

"The health of the people along the river is better than that of those living in the foothills or the highlands. I have noticed no difference as to malaria. I have had cases of typho-malarial fever, so designated. I consider typho-malarial fever a malarial fever that, owing to intestinal irritations assumes a typhoid character." (3265-6.)

Meredosia.

Nine witnesses were examined at this point, which is a few miles above Naples.

The following testimony is indicative of the character of the testimony given at this point.

Julian L. Graham testified as follows:

"Am a fisherman. Live at Meredosia. In 1900 the water of the Illinois River was very foul, very low and navigation was almost impossible at times. There was an odor connected with the water.

"It has been so low and so foul that it was almost impossible to go bathing. There was a scum on it to such an extent that a person could hardly pull through it at times with a boat. Since the opening of the Canal we haven't had any low water. The effect of the opening of the Canal has been the best in the world for navigation, sanitary considerations and everything else in that line. There has been no

smell since and no scum. I believe it has purified the water itself to a great extent during both winter and summer. Before the opening of the Canal there would be a scum on the nets. I don't know as I see much difference now, only it has been an improvement. I don't think I see as much slime and stuff accumulate on the web.

"I suppose there would be about 80 or 90 fishermen engaged in the fishing business at this place. Since the opening of the Canal, I don't know of any typhoid fever among the fishermen." (3215-16.)

Dr. A. F. Neville testified as follows:

"Have been a practicing physician for over 16 years. Before the opening of the Canal, in the fall the river water would become rather stagnant and green and there would be a good deal of organic material in the water and floating. There was very little current in the water, to speak of.

"I believe the opening of the Canal has improved the character of the water. The water is more clear and there is less organic material in it. At least I would judge so from the appearance. My practice extends among the fishermen as well as other people. I think there are between 50 and 100 fishermen here. Have had no typhoid fever cases during the last three years from the fishermen, and have not had to exceed one-half dozen cases during that time in Meredosia. None of those cases were attributed to the waters of the Illinois River. In those cases that I had the excreta was disinfected, and some of it dumped into sink basins and others dug holes; at least that was what I ordered done. Meredosia has a population of about 800." (3227.)

S. D. Allen testified as follows:

"Live in Meredosia and have lived here about 25 years. My business is pumping water out of the Illinois River into a tank for the Wabash Railway Company. I began pumping water in 1896, I think.

"Prior to that time I was working here on the bridge about four years. Before the opening of the Canal, at low water, the Illinois River was pretty filthy in my estimation. There was green scum on the river and grass growed all up in the water here, and a sediment in the river. The water went down and left all the filth on the ground outside. It was a pretty bad stench here as soon as the water went down and left it. The water acted bad on the boilers before the opening of the Canal. It foamed in the boilers. The opening of the Canal has been a benefit to the water. The water has been purer. We have used it for drinking purposes on the bridge right along when it was cold enough to use it. There is no odor that I could discern. I haven't seen any of that scum on it. It has been better for steam making purposes. It has not foamed and has not lined the boilers as bad. We drink the water there on the bridge all the time when it is cool enough. Drinking of the water hasn't made any of us sick that I know of. The water now is better. It hasn't got that gas or stench to it that it had before. It is more clear and it is purer I think." (3229.)

Naples.

Naples is about 38 miles from Kampsville and about 36 miles above Pearl. Five witnesses were examined at this point.

Benjamin Franklin Eckles, whose testimony is here reproduced is similar to that of the other witnesses and is as follows:

"Have lived upon the Illinois River about 15 years. For four years I have lived within eight feet of the bank and that is where I live now. I have lived in this vicinity since 1846. Prior to the opening of the Canal when we had a little rain the river was muddy and whenever we had a long dry spell it was clear. There was considerable moss and even

grass, but that was years ago. There was a smell to the water in warm weather. Since the opening of the Canal I pronounce the water clearer, purer, brighter and better and use it stronger for all uses than I did before. The last four years, I have lived on the river and I have used that river water a good deal for all purposes. In right warm weather I don't use it for drinking but in cool weather I do. In cool weather I use it for drinking, cooking and everything.

"The people have splendid pumps here. I haven't suffered from any disease caused by drinking the water, that I know of. I enjoy good health for a man of my age.

"Cross-examination:

"I am 65 years old. Have a better current now than we did before the Canal was opened." (3209-10.)

Pearl.

This point is about ten miles above Kampsville. Testimony of four witnesses was taken. The testimony of Marion Hess is similar to that of the other witnesses. It is as follows:

"Live in Pearl. I fish and farm some along the river. Have fished off and on for ten or twelve years, 15 miles each way up and down the river. Before the opening of the Canal the river was pretty filthy and bad.

"During July and August it was pretty filthy, green-looking water. It would form a scum and slime all over the nets. During this time when there was slime and scum upon the waters we drank it, along in the spring of the year. Since January, 1900, the water seems purer and all right. There is a good current. Now whenever I want a drink of water I take the cup and get me a drink most any time. When I can get no other water it does pretty well. I don't know exactly

as I know of any typhoid fever among the fishermen since the opening of the Canal. I couldn't mention any around here." (3168.)

Gravel Point.

Five fishermen testified at this point, which is about 40 miles above the mouth of the river. The testimony of John Weimer, which is given here in part is similar to that of the other witnesses. He stated:

"Before the opening of the Canal the Illinois River water in low water was stagnated fearful, it was greenish. Since the opening I consider that it has been lots better. I consider it purer now than it was before. It hasn't the odor. Six or seven families are engaged in fishing at this point. I do not know of any typoid fever among those people. I have drank the water of the river nearly altogether for 12 years both in summer and winter. It is lots better now for drinking purposes than it was before." (3153.)

Kampsville.

Kampsville is located about 30 miles above the mouth of the Illinois River and at this point is located Kampsville dam, which is the last dam appearing in the Illinois River before its mouth is reached.

Seventeen witnesses were examined at this point, their testimony corroborating the testimony given by the following witnesses:

James Morain testified as follows:

"Live at Columbiana, Green County, Illinois. Have been a fisherman for 15 years.

"Before opening of Canal this River was like a pond here; filthy stuff and a green scum. Smelled some; especially about nine o'clock of a morning when there was no draught that the breeze raises. The moss and slime was bad; plenty

of it, all covered; it took two men to get them out sometimes. Since opening of Canal we have had a much better current; the water has been much better in my opinion since the opening of the Canal; that is, it don't smell. In warm weather we take ice and put it in the river water and use it. The water of the Illinois River when you drink it, does not produce disease. I have lived right here 14 years and I have never had a chill. Neither I nor my family have had typhoid fever. The fishermen who drink the water do not have typhoid fever as I know of. I don't know of anyone here that has had typhoid fever at this place. Have assisted in putting up ice. Since opening of Canal the ice is very nice if we have a head raise on it; that is, it is clear ice. Of course, if we have a head raise you know, there is more muddy water settles in it." (3063-4.)

Ira Davidson testified as follows:

"Kampsville is my postoffice. Am a fisherman and have been for year and a half. Came here from St. Louis. Lived in St. Louis two years and prior to that time lived in Green County, Illinois. I lived 8 or 10 miles from the river, but I crossed the river twice every week for about 3 or 4 years. Before the Illinois River was low and no current practically.

"The water was dark and had green scum on it. Since opening of Canal water has been clearer and we haven't had any scum or grass. There has been no odor. Have been on the river 18 months out of the last two years. Drank the water as often as half a dozen times a day. Never taken a dose of medicine since I have been here. About 40 fishermen are engaged in fishing at this point. They are in the habit of drinking the water of the Illinois River when out fishing.

"There has been no typhoid fever or sickness in this community during the last 18 months, that I know of. Opening of Drainage Canal has made the water better." (3068-9.)

C. V. Brainard testified that he was a civil engineer in

charge of the Government improvement of the Illinois River since February, 1891.

"At low water the waters of the Illinois River got very bad before opening of Canal. There would always be a greasy sort of a scum on the top of it; it would frequently be green the whole depth of the river. There was always more or less of an odor to it. It hasn't been as bad since the opening of the Canal. There has been more current and there hasn't been that bad look to it; it has always looked clearer and better than it did before. The color has been better. Before the drainage water was turned in we frequently had grass growing in the river up to the side of the channel where the steamboats kept it worn away; since the water of the Drainage Canal has been turned in I have seen none of that.

"I don't think the water of the Canal has injured the waters of the Illinois at all; there has been improvement for the time it has been in, over what it was for certain years before. There was one case of typhoid in Kampsville since the opening of Canal. That was the doctor. He had been attending typhoid patients back from the river and we suppose he got it from that." (3099.)

Frank Tozier states that he is a steamboat engineer and has been for fifteen or twenty years and at the time of the taking of the testimony was in the employ of the Government as engineer of United States dredge boat.

"We drink the water of the Illinois when we are out dredging. We use the water with ice. Don't use ice water when water is cool. The water does not give us any disease. The Government fleet now on the Illinois River consist of 3 barges, 3 steamers, 8 dump scows, 4 flats, 2 quarter boats and an officer's boat. 40 or 50 men are employed on this fleet. These men generally drink the water of the Illinois River. It doesn't seem to have any bad effect upon them. Most of them are in good health the whole thing through. Once in a

while there will be one that will have a chill. Prior to opening of Canal you could find this whole river here as far as you could see covered with a green slime all over it. We don't have that and haven't had it for the last two years. May be one of the hot days you may see a little streak of that green right where the channel comes, but very little of it. The water now with ice in it, I believe would be perfectly healthy right at the present time. I believe it will be fit to drink the year around. After the weather begins to get cold in the fall we drink it right out of the river. (3105.)

Valentine Totzell testified as follows:

"Am a fisherman. Have been a fisherman since 1874 on the Illinois River. Live at Kampsville. Prior to the opening of the Canal the river was stagnated water—green. I have seen it here one season when the water was green fully six inches deep. If you dipped up a bucket of water it would be perfectly green. There were times that there was a kind of a bad smell, coming in kind of puffs like. Since the opening of the Canal we have had better water, that is, say six or eight weeks after the Canal was let in, we had pretty bad water, the water was colored. At the same time it was cold weather; it was kind of coffee-colored brown, but then six or seven weeks after that it cleared out and we have had good water since. We have got a better current now than we generally have.

"There is no smell that I could catch. I drink the water now regularly. Before the ditch was in, we couldn't drink it at all. Drinking the water has had no effect on my health that I can see. I have always been hardy since I have been on the river. If turning in the Drainage Canal had any effect at all, it would give us better water—I mean purer water and more of it. Before the opening of the Canal there was several times when the river was very low that we had no current at all and it was dead water above the locks here.

Three times I have raised, all the fish in my nets were dead. There was a kind of slime formed on the nets.

"Since the opening of the Canal the fish keep better in live boxes and you can leave them longer in nets without raising them and they won't bruise themselves or die with disease as they would before." (3112.)

James R. Fuller states that:

"Live at Kampsville. Am in government's employ as overseer of Illinois River crew.

Prior to 1900 the current of the river, especially in low water was sluggish and the river was always muddy. In low water it smelled pretty strong a good deal of the time. I think the water has been clearer since the opening than it ever was before and there is a good deal more current. The men under me that worked in the dredging operations drank the Illinois River water before and after the opening of the Drainage Canal, part of the time. Occasionally there would be a spring near where we were working and they would drink that water, otherwise they drank the river water.

"There has been no typhoid among those men to my knowledge." (3146-7.)

Hardin.

Hardin is about 15 miles above the mouth of the Illinois River. Chas. Flamm testified as follows:

"Am an insurance agent. Before last fall was county clerk of Calhoun County. Live in Hardin. Have been acquainted with the Illinois River at this point (Hardin) for the last ten years.

"In my opinion the water in the river prior to the opening of the Drainage Canal wasn't as pure as it is now. Prior to opening of Canal the low water on the river on the east side was covered with vegetation and it looked to me as if the

water was very impure. There was scum on the water. It was a greenish scum and when you passed through it with a boat it left a trail. You could notice it for some time afterwards; that is when the river was rather low; low water; during the summer months. Since the opening of Canal it has a better current and this scum no longer appears. I did not drink it before. About 12 or 15 fishermen are engaged in fishing at this point in the river.

"I do not know of anyone who had typhoid fever or who died from typhoid fever in the last two years at this point. In my opinion from the appearances, the water has improved since the opening of the Drainage Canal in January, 1900." (2995-6.)

Edward Athy states that he has lived in Hardin about 20 years. He further states "By the appearance of the Illinois River it has improved since the opening of the Canal. My judgment is only from appearances and the water appearing clearer and cleaner. I should say that it is purer. Have not noticed any odor in the water since the opening of the Canal."

On cross-examination he stated:

"My opinion is the waters have been improved by the increased flow. I have not observed here anything in the Illinois River that would lead me to believe that the sewage from Chicago was present in the waters of the Illinois at this point."

M. E. Fisher testified as follows:

"Am merchant, reside in Hardin. Have lived here 35 years—all my life. Am acquainted with the Illinois River. Got acquainted by being on it all my life. I fish with a hand line. Before opening of Canal so long as river was down low and green grass growing in it and scum all over it, it made a smell. When a skiff went through it left a track through the grass and scum. Since the opening of Canal the river is up higher and clearer and swifter current; better water.

Drank waters of the river before and after opening of Canal. Think the water is in good condition here now. It is better since the opening of the Canal. The river is clearer and swifter current. About 10 or 12 people are engaged in fishing business at this point.

"Don't know of any deaths from typhoid fever in this locality. Am acquainted with all the people in this town. Everybody knows each other here and each other's business." (3002-3.)

Abner Poor testified as follows:

"Live in Hardin and fish for a living. Have been a fisherman about 28 years. Fished here prior to 1885. At that time the river along in summer and fall, I don't know what you would call it, but I would call it poison; more poison than water. There was a green scum on it; no current in it nor nothing. You could put a net in the water and raise it up, you know, and it would just be hanging in tags.

"Was not aware that in 1885 the City of Chicago pumped its sewage into the I and M. Canal and continued that until 1900.

"The water is more pure and better now than it was in 1885 at this time of the year, it has been in the last two years. I know the water is better now than it was then. Before 1900, for 15 years, the water in the Illinois river was substantially always in the same condition. It was low, no current, and most awful dirty and nasty. This dirt and nastiness come from the stagnated water, as far as I know—it couldn't come from anything else but the stagnated water, that I know of; it was just like one of these ponds. In the water if you cut a hole in the ice a kind of nasty green scum would come up in that hole and you would pull a net up and it would just be tags hanging all over it. Those tags were filth from the dead water. Lots of fish died under the ice. I have drank

the water ever since I have been fishing. I never pretend to take spring water or well water with me at all.

"When I would be seining and pulling the sein where it was shallow and this grass growing in it all rotten, it smelled pretty bad there. Since the opening of the Canal the water has been more pure and it tastes better, too. We don't have any more moss and filth in the river since that. We don't smell it any more, the current takes off the filth and smell.

"My fishing operations have extended from 12-Mile Island to Kampsville. That is about 16 miles by river. I never knowed a fisherman along the Illinois River to have typhoid fever. As a general thing the fisherman is the hardiest thing there is along the river. The fishermen, the majority of them, generally drink the river water. That is I can say that much for the fishermen around here; none of us carries water with us no matter how far we go."

Cross-examination:

"My fishing trips have made me acquainted with the Illinois River for a distance of about 18 or 19 miles. I am 61 years old and have been fishing right here for 28 years.

"We had no current at all before the Canal was opened. When a skiff got loose was as apt to go up stream as down stream. Just like this spring when the Mississippi was backing the river up. I say the water is better now than it was before the opening of the Canal for the simple reason it tastes better now. Better fishing now than there was then. Water is deeper and there is more of it. Before Canal was opened you could take a tin cup of water and let it set and there would be a thousand little worms in it, just like you get in one of these ponds, and dip it up, like wiggle-tails. That is not the condition now."

Re-direct examination by Judge Johns:

"Before the opening of the Canal fish lived 24 hours in live

boxes. Now you can keep them for four or five days—I kept them that long last summer. Fish are livelier and appear better—they have got more life about them than they had before and there is more of them, too." (3004-9.)

G. A. Williams testified as follows:

"Live at Hardin. Practicing physician. Practiced 22 years at Hardin. Been engaged in the general practice among the people. Prior to opening of Canal water was at times stagnant; during summer had an odor arising from no current and stagnant condition; odor arose from decaying vegetation and perhaps sewage, too. Since opening of Canal it is much better—much improved.

"I suppose people living along river use water for domestic purposes and drinking to some extent. Prior to opening of Canal there seemed to be a good deal of typhoid fever among people living along the river. Since opening of Canal we haven't any case, at least I haven't had any. Ice taken from river is clearer and better ice since opening of Canal than it was previous." (3015-16.)

M. J. Parker testified as follows:

"Live in Hardin. Lived here since 1873 with exception of five years I was on my farm in Jersey County. I run on Illinois River for 4 years, steamboating, from St. Louis to Montezuma and part of the time as far as Naples. It is 32 miles to Montezuma and we call it 50 miles to Naples. Am in orchard business at present.

"Quit steamboating in 1899 but have been on river hunting and fishing every season. Before opening of Canal it was a very sluggish stream and it looked like there was an accumulation of moss and grass and the stench was pretty bad at times, especially in warm weather and low water; the water had a kind of a greenish appearance and very little current. There was considerable of a scum on the water at times, especially when we had a continued drought, and low

water; it would be a good deal more than it would be in the wet season; when the water was coming in from the draw, that is after heavy rains, it would clear it up considerable.

"Since the opening of Canal I consider there is quite an improvement in the appearance of the water; it looks cleaner and purer and we have got a decidedly better current, and it tastes better; it is not so sickly and such a flat, filthy taste. I have drank the water since the opening of the Canal. Early in the year the water is too warm; take the ice along it makes it very nice. When I go fishing I take ice with me and drink Illinois River water. I don't think I ever experienced any deleterious effects from the use of the water.

"It is 100 per cent. better now than before the opening of Canal. I base my conclusion on the condition of the water and the appearance of it, and the life and the current we have and the tasting of it. Of course, I don't want it understood that I am an expert on this, but then it was in a fearful condition prior to the opening of the Canal, especially in hot weather and at low stage." (3020-1.)

Elmer E. Williams testified as follows:

"Cashier of Bank of Calhoun County. Lived in Hardin since February, 1899.

"From February, 1899, to January, 1900, we had a swimming club and would go swimming down at Rocky Bar about a mile below. The water got so foul along in July and August, about August, I guess, that we couldn't go in swimming any more. There would be a green scum on the water and a very foul odor; very turbid. And it was very low, too. We could observe the odor from where we lived; we lived about two blocks from the river and the street runs right down to the river with no buildings south of it; it was very offensive. Since opening of Canal there was no green scum formed and no perceptible odor like there was the previous year, and that condition has been, I think, improving for the better

as to the sanitary condition and clearness of the water and less foul. The Sanitary Canal waters have purified the Illinois River at this point; the Drainage Canal has purified the water." (3037.)

Wm. McNabb testified as follows:

"Am druggist. Been living in Hardin about six years. Have been on Illinois River a good deal boating and have been fishing. The water in 1899 was very low, the stage of the water here, scarcely any current and the condition of the water was not as good as it is now by any means; there was a scum over the river during that year, a green scum. There was an odor to the water. Since the opening of Canal we have had a better stage of water, a good current, and we have no scum over the water and there is scarcely any perceptible odor now. The water is a good deal better than it was before the opening of the Canal. My observation leads me to that conclusion. I am the only druggist in town. I disremember of a case of typhoid fever in town since opening of the Canal. There has not been as much malaria in this community since as existed before opening of Canal. I know the chill tonics and preparations for that complaint; we haven't sold since the opening of the Canal one-third or perhaps one-fifth as many as we did before." (3040.)

Jefferson Welch testified as follows:

"Am a fisherman. Have been in that business 21 years. Fished in Illinois River mighty nigh all the time. Of course I get over in the Mississippi sometimes in June or July, but then I fish kind of steady here. Fish with nets all the time. Fish about 18 miles north and about that far down the river. Prior to opening of Canal Illinois River was low in summer, full of moss and no current. Moss covered the nets; green moss. Would have to take it off with my hands; sometimes let it dry and knocked it off. Don't think the fish were as good as they are now. Haven't in the last few years seen

dead fish along the banks like I used to see. Since opening of Canal, water has been more pure, more current and there was not near as much sickness; wasn't near as much fever and ague along the banks or low lands as there was before.

"Condition of the fish is better. They live longer in live boxes if you keep the live boxes in the current. As a fisherman I drink the waters of the Illinois River. The drinking qualities of the water now are better than it was; more cooler, the water drinks better. Fisherman along the Illinois river generally drink its waters while they are fishing. Don't know of any typhoid fever among the people drinking the Illinois River water since the opening of the Drainage Canal. Have been engaged somewhat in assisting in putting up ice. It seems like to me the ice is more clearer than it was before, more solider and more bluer than it was before." (3048-9.)

Twenty witnesses were examined at this point and testified substantially as did the witnesses whose testimony is above quoted.

The witnesses included doctors, lawyers, fishermen, bankers, editors, etc., and their testimony appears in the record beginning with page 2994 and ending with 3052.)

Grafton.

Grafton, Ills., is located on the Illinois River right above its mouth, the Illinois River discharging into the Mississippi a short distance below the City of Grafton. The distance from Grafton to Peoria is 160 miles and from Peoria to Chicago it is also 160 miles, making the total distance from Grafton to Chicago 320 miles.

V. J. Schumacher testified as follows:

"Live at Grafton. Am pilot on the Illinois and Mississippi Rivers. Have been pilot for six years.

"Prior to that was steamboat engineer or mate, either one, for 14 years on the Mississippi and Illinois Rivers—mostly on the Illinois. Have been acquainted with the waters of the Illinois River for 32 years from St. Louis to La Salle, Illinois. Prior to the opening of the Canal the water of the Illinois River was green. The water from—well, we will say from Beardstown up—it stunk. We could not drink the water, it would foam the boilers, but now we can go along and drink the water. We pump the water and use it on excursion boats—before we could not.

"Before the Canal was opened it had a green scum on it. It smelled bad. It was not fit to drink. We would have to get water from the shore, but since the Drainage Canal has been opened we don't have to do that. Before the opening of the Canal we would find dead fish floating in the river—tons of them—floating in the river above these dams. Since the opening of the Canal we have had better water and better fish.

"Those dead fish were found at Copperas Creek dam and also at the dam below Beardstown, also at Kampsville. We found them up there every time we would go through. We found the green scum plumb up to La Salle. It would generally go down about to Peoria before it would begin to vanish.

"Of course, further down the river the water would naturally become more pure on account of the current in the river. Those distilleries at Peoria would have great piles of stuff in the river. We don't see that any more. The water was always better above Peoria than below. It was some better than it was below because it was stiller up there, because the sewage business could not go the river and consequently it didn't have this bad green smell and look to it that it had below Peoria always. We find we have a good deal better water in the channel now than we had before. Before the opening of the Canal we never drank the water at all. We would dig

holes along the banks or the shore, or sink pumps down and get the water that way.

"In my opinion as a layman and a man who has observed the conditions along the river, the water has been better since the opening of the Drainage Canal. It has been better to drink and better to use in every way. The green scum has not entirely disappeared but more so than it ever was before. The odor of the water has disappeared and the water has become clearer than heretofore.

"I believe the water at Grafton is better now than it was before. There is a good deal of difference between the water at Grafton and at Pekin. It is like a man taking a drink of river and taking a drink of spring water, like where there has been rotten fish or somebody had been laying in it. I would not want to drink the water there. Here, we drink the water all the time when we are out in a skiff." (2935-9.)

Upon cross-examination this witness testified:

"I am not attempting to give the reasons why the water since the opening of the Canal is better than it was before. I am simply stating what in my opinion is a fact.

"The main reason I say the water is better is because the water is better and I know it is better from using it and the hundreds and hundreds of people that we carried on the steamboats using the water and not kicking against the water." (2943.)

Dr. Wesley Park states that he has lived in Grafton 14 years and has been a practicing physician for 43 years and is still engaged in that business. He further states:

"Am acquainted with the Illinois River between Grafton and Hardin, but not much above Hardin. Hardin is about 30 miles from here by river. I did not notice any difference in the water at Grafton and Hardin prior to the opening of the Canal.

"Since the opening of the Canal the water at Grafton is

better, purer, cleaner and has greater current. Before the opening of the Canal the water at Grafton was sluggish, had more or less green scum and moss, the current was not as swift and the water was more of an impure character. There are two doctors in Grafton. I cannot call to mind any case of typhoid fever among the fishermen in the last three or four years. I don't know of any cases that I have attended during the last three years that I could attribute to zymotic causes—that is, of typhoid character that could have been caused by drinking Illinois River water. Between here and Hardin I certainly know of fifty fishermen engaged in the fishing business. From a knowledge based upon appearance and use of the water, I would say that the waters are much better than they were before the Canal was opened and I mean by that, its appearance. It has a purer appearance." (2953-2954.)

E. Meyzenburg testified as follows:

"Have lived in Grafton since 1867. Am sole proprietor of the Grafton bank and am in the merchandising business. I have always been fond of the river. I keep a boat of my own and have always spent considerable time fishing, hunting, etc., on the river. I live on the bank of the river. I am familiar with the river up from Grafton I should say 14 miles.

"Since the opening of the Canal the water is not stagnant as it was previous to the opening of the Canal. To my mind it looks much better. My well and cistern were flooded during this high water and I used water out of the elevated tank for domestic purposes during that time, which was since the opening of the Canal. That water came from a well that was fed by the river. It was June 11th when the water flooded my well. I have used it up to the present time (July 14) but had my well cleaned out to-day. My family has used it to a certain extent.

"There has been nobody sick at my house. Prior to the opening of the Canal the Illinois River frequently looked like a stagnant pool. There was a scum on it such as would form on a pond that had no current in it. There is now a decided current in the river. As to the fishing industry here, I have known as high as 12 tons to be shipped from here in one night."

George Seik testified as follows:

"Live at Grafton. Am a fisherman. Have been a fisherman since 1892. Have fished in the Illinois River every spring. Before the opening of the Canal the water in the summer time was a good deal like a pond. The curernt would leave it and a green scum would come over it. When we had a heavy raise, there would be a good deal of current in the river. The water would smell like stagnated water in the summer time. The water never smelt in the spring of the year but when it had this green scum on it it smelt like a stagnated pond. The water had a kind of milky color as near as I can tell. Before the Canal was opened we drank it right along in the spring and fall. In the summer time we wasn't in the Illinois very much in the hot weather. If we should happen to be there and had no water we would drink it then. In the fall of the year there would be moss on the nets. Since the opening of the Canal there has been more current, therefore I think the water is purer than it was before. The water tastes cool and it must undoubtedly be better to drink because there is more current in the water. It is a purer water.

"There are 20 or 30 fishermen from my own place. I don't know of any typhoid fever among the fishermen in the last three years." (2968-9.)

Albert Freimann testified as follows:

"Live at Grafton. Have been a fisherman 19 years. Fished in the Illinois River during that time. Before the opening of the Canal the Illinois River would be kind of stagnant dur-

ing the summer season. When it got down low it was a kind of a dark black. In that condition it smelled like a pond or an inland lake. The moss and stuff would get on to our nets. We drank it in cool weather. Since the opening of the Canal the water seems to be much purer than it was—more current I suppose, is the reason. I drink it since the opening of the Canal during the cool weather. It seems like it is a kind of milky light color. In cold weather all the fishermen that I know of, drink it.

"No one that I know of has typhoid fever. I have cut ice here every winter that they cut it for over 20 years. I don't know as I notice any difference in the ice now to what it was before the opening of the Canal. Moss hasn't as yet gathered on our nets since the opening of the Canal. I have fished up the Illinois River 15 miles."

Cross-examination:

"The water isn't exactly the same color as it was. I never paid much attention to the ice. Before the opening of the Canal the water was of a rather dark color and since the opening it has a kind of a milky-like color. It looked like you might take a drop or two of milk and drop it in a glass of clear water.

"It seems that there was more chills and fevers around town before than there has been since. It was kind of an ague fever, I guess, it wasn't typhoid fever as I know of." (2971-2.)

William Wright Crandell testified as follows:

"Am a fisherman. Reside in Grafton. Have been fishing since 1896 in the Illinois River above Grafton. Before the opening of the Canal, water in the Illinois River was stagnated, unless we had a head raise. It was dark in color. It didn't have a pleasant smell by no means. It affected the nets pretty badly. It covered them all over. It was mostly slime first. It would come on the net and hang down in pieces

that long (indicating) as thick as your finger and then the moss would come and cover the nets so heavy you scarcely could lift them.

"It wasn't so good to drink then. I have fished there now since the opening the canal, within the last two years, in April and up to that time the water was pure and reasonably clear, with the exception of the leads that would run into it, you know, and in heavy rains. There hasn't been any odor to the water since. The fishermen on the Illinois river who drink its waters have not had typhoid fever." (2975.)

Thomas Cockschott testified as follows:

"Live at Grafton. Am a fisherman. Fished in the Illinois River every season for 20 years.

"Before the opening of the Drainage Canal, the Illinois River after the spring rise was dead. Now there is a good deal of current in it and has been for the last three years. Whenever it comes a raise it is a dirty color, it is muddy and dirty. It is clearer now than it was before the opening of the Canal. I drank it before the opening of the Canal. In hot weather, when it was warm, it was pretty tough to drink. It is better to drink now than before the opening of the Canal. It is clearer. The moss on our nets before the opening of the Canal was worse than it is now. I have engaged in putting up ice. I believe it is clearer now than it was before the opening of the Canal. Fishermen on the Illinois River haven't had typhoid fever either before or since the opening of the Canal that I know of." (2979-880.)

Martin Gilmore testified as follows:

"Live at Grafton and am a fisherman.

"I have fished in the Illinois River every year for 12 years. Before the opening of the Canal the Illinois River at certain seasons the water was dead. There was no current. It had a scum on it. Since the opening of the Canal there is a pretty fair current in there all the time. We never see no

scum up there now. Before the Canal was opened there was times that slime and scum smelled very bad, when the water was dead and had no current. We seined up there one year when there was no current and we couldn't seine over three or four hours. If we would catch any fish we would have to come down here and ice them. They would spoil right away, but since the opening of the Canal it seems like the fish live better. I have drunk the water both before and since the opening of the Canal. The water seems to be more clearer now than it used to be and it is clearer.

"I never heard of fishermen in the Illinois river having typhoid fever. I have never known of but one fisherman to die around here that I can remember and he was an awful old man. Have engaged in putting up ice and it seems to me the ice is clearer than it used to be. There ain't the dirt in it and there ain't as much drug in it as there used to be." (2982.)

E. A. Sawyer testified as follows:

"Live in Grafton. Have been a fisherman for ten years. Fish in the Illinois River every spring. I think the water is in better condition now than it was before the Drainage Canal was turned in.

"Before the Drainage Canal was turned in, it was like a lake or a pond. Green scum on the water and moss all over the shores. The water was really a dark green and to-day the water is clearer and purer looking than it was before. I prefer drinking it now better than then, as far as I am concerned. I drink the water in the spring of the year. Haven't experienced any ill effects from the water since the opening of the Canal. The fish live better to-day when we take them out of the net than they did before. It don't form a scum on the nets like it used to. I never knew but one fisherman to die since I have been in Grafton and he died with heart disease. He was about 65 or 70 years of age." (2988.)

About a score of witnesses testified substantially to the same facts as are related by the witnesses above referred to, beginning on page 2905 to 2992 of the record.

The following witnesses testified to conditions along the entire course of the Illinois River.

John M. Hipple, a pilot on the river in the employ of the Federal Government, testified as follows:

"Before opening the Canal the water of the river at low water got very filthy and green. Filth was caused by lack of current to drive it away. Filth was from both decayed vegetation and from sewage but mostly from sewage. From Peoria to La Salle in low water it was filthy and dirty. It seemed to be more filthy about the Henry lock.

"When we got over the Henry dam it got better, when we got down to Peoria or down near Peoria. The stretch from Peoria to Copperas Creek dam was very bad, very bad. It was a good deal worse down below Peoria than it was above. I think it was on account of sewage from Peoria—no current to drive it away. Since the opening of the Canal the water below Peoria and the Copperas Creek dam is much improved. I was over it yesterday and it looks as well as the river down here.

"Prior to opening of Drainage Canal the water between Copperas Creek and La Grange was a good deal better than it was before; after it went over the dam it didn't get bad again until it got down to Beardstown, or near the other lock—down to La Grange lock. Since the opening of the Canal that stretch of water seems to be a great deal improved. Before opening of Canal the stretch of water between La Grange and Kampsville wasn't near as bad as it was up above Copperas Creek, but it is better now than it was then. The river is in better condition now than it was then.

"Prior to the opening of the Drainage Canal the water of the Illinois River improves as it travels from La Salle to

Peoria Lake. Since the opening of the Canal the water from La Salle to Peoria improves as it travels. Prior to opening of Canal the water immediately below Peoria was in worse condition than at La Salle. The water below Peoria was the worst; the water above Peoria was the best."

"Q. Did the water (prior to the opening of the Canal) as it traveled from Peoria to Copperas Creek dam improve in appearance?

"A. No; it seemed like it got worse until after it came over the dam and then it seemed to improve. It had to come to Pekin, you know, and there it got mixed with a lot more. Between Peoria and Copperas Creek dam there was a large amount of sewage and offal added to the water in the river at Pekin. Before the opening of the Canal the water in the Illinois River appeared to improve between La Grange and Kampsville and between Kampsville and Grafton. Since the opening of the Drainage Canal the waters of the Illinois River appear to improve between La Salle and Peoria. The waters in that stretch of the Illinois River are better since the opening of the Drainage Canal than before.

"Since the opening of the Drainage Canal the waters of the Illinois River between Coperas Creek dam and Peoria are better as compared with their condition before the opening of the Drainage Canal. The water looks better. Since the opening of the Drainage Canal the waters of the Illinois River between Copperas Creek dam and La Grange dam are better and purer and not so much vegetation and green stuff. The further down this way the better the water is. Between La Grange and Kampsville the waters of the river are better since the opening of the Canal. Since the opening of the Canal the waters below Kampsville dam to Grafton are improved some; the waters are better, but you can't notice it here like you can on the upper end.

"Q. Since the opening the Drainage Canal, you may state

whether the waters of the Illinois River gradually and steadily improved from La Salle to Peoria Lake.

"Objected to as leading, and misleading.

"A. Navigation improved, yes, sir; wonderfully. It looks clearer. From La Salle to Peoria the water looks clearer.

"Q. Since the opening of the Canal do the waters of the Illinois River improve between Peoria and Copperas Creek dam, and if not, state why?

"Objected to as leading and suggestive.

"A. Yes, sir; they improve.

"The amount of offal and sewage these waters receive at Pekin is considerable.

"Since the opening of the Canal the waters of the Illinois River improve in condition between Copperas Creek and La Grange; between La Grange and Kampsville and between Kampsville and Grafton." (3082-6.)

J. P. Bauer testified as follows:

"Am a fish culturist in the employ of the U. S. Fish Commission. Am at present in charge of the station at this point of the U. S. Fish Commission at Meredosia. I have been employed in that position about 14 years. I look after the collection and loading of the U. S. Fish Commission cars. Seven men compose the crew, not including myself.

"My duties give me an opportunity to become acquainted with the Illinois River. Up to five or six years ago, I had charge of the Steamer "Lotus" in making collection of fish for distribution by the U. S. Fish Commission. I became acquainted with the river from La Salle to Grafton. The fish we handle for the U. S. Government are black bass, croppie, channel catfish and bream. There are lots of other fish that we handle as a collection, put up in formalin and send to Washington. Before the opening of the Canal, the river between La Salle and Grafton, during the summer months, the

water would get very low and the water was in what I would call bad condition. So much so that you couldn't drink it, even by the use of ice in the water. From Copperas Creek dam for about five miles above it, I have gone up that stream in the steamer "Lotus" and turned up sediment and dead fish and on several occasions there was a terrible stench and a man could hardly stand the smell, which I suppose was from the distilleries, or I believe it was the filth of the distilleries at Pekin and Peoria. (Motion by Mr. Jeffries to strike out.) I know that there were distilleries at Peoria and Pekin, but I didn't know there was a glucose factory at Pekin or Peoria. At low stages the water in the Illinois River would not affect fish so far as I know, in ponds. I don't know that it affected the fish below these dams any at all, only during the winter season when the ice was over the water after the ice was broken up, we would find quite a number of dead fish. Those ponds I speak of are fed by the Illinois River when the water is high enough to go back into them. I have seen thousands of dead fish in these ponds. They were eaten by the different kind of water fowl that we have around this country.

"During the winter time I have noticed similar conditions as existed from Copperas Creek to Peoria, at La Grange locks. I don't know of any complaint ever having been made about any stench around La Grange locks. At this point, before the opening of the Canal there was nearly all the time a green scum on the water. We always had a current in the river. The channel would perhaps not be over 75 yards wide and vegetation would grow for about 100 yards from the channel bank to the east, to Meredosia. There would be a smell but I don't know whether you would lay it to the water or the fish. This is a great point along here for fisherman to throw off the offal of fish and it might have been that. That offal is thrown into the river at this point. The effect of turning the water of Lake Michigan into the Illinois River

has been to make the water clearer and we have a three-foot high stage of water from low water mark. I could drink the water now in the Illinois River to-day if it had ice in it. I wouldn't have done so previous to the entering the Chicago River, unless it was absolutely necessary to do so. I have noticed a green pod that floats on the water since the Canal has been opened, but it isn't scum. It might be taken for scum in looking at it from a distance. It seems to come from some tree or perhaps grows right in the water, I don't know. In my opinion the Illinois River has been greatly benefited by the opening of the Canal." (333-5.)

Michael D. Hurley testified as follows:

"Live in Peoria. Am doing special work for the fish commissioners. Before that I was captain of police in Peoria and before that wholesale fish dealer. Prior to the opening of the Canal, below Peoria the Illinois River at low stage was muddy, mixed with manure and what we used to call slop. It was pretty strong smelling. Above Peoria in Peoria Lake and the lakes above here, it was covered with green scum during the warm season. The water itself looked green. It smelled badly with a different smell than below. There were times both winter and summer that fish used to die in numbers; in the winter more particularly above Peoria; in the summer, just from the distilleries on down. Since the opening of the Canal there has been an absence of the scum, and the smell has disappeared almost altogether, except a little below the city proper here. The water was clearer apparently, and better. There are two bridges below Peoria. Below the first one the water is now quite good and a little below that it is bad. It is riley and muddy and discolored somewhat. That condition is noticeable pretty well all the way down the river to the Havana territory. Opposite the distilleries the condition of the river is bad. It is filthy; lots of bubbles; plenty of those little patches of bubbles floating down all over. That condition continues pretty well down

to Pekin; then it clears up somewhat, and then it begins again and extends below Pekin for six or seven miles. The water above Peoria seems clearer and better in every way than that below Peoria. Knowing the river as well as I, my opinion is that the opening of the Canal has had the effect of purifying it. I think it is true to a considerable extent below Peoria as well as above." (3577-8.)

R. R. Bourland testified as follows:

"Reside at Peoria. Am in real estate and loan business. Am Secretary of Illinois River Valley Association. The object of the association is to look after the interests of the residents in the Illinois Valley in relation to the use of the river itself. Have been connected with the association since 1897. Lived in Peoria all my life. Before opening of Canal Illinois River was an ordinary, sluggish stream that was disagreeable in low water. The river above Peoria was as I said an ordinary prairie stream; below Peoria it was very much affected by the drainage of Peoria, and was a much more disagreeable stream below. There was certainly an odor from below Peoria; I am not so positive as to the fact of the odor coming from above. Since 1900 the water above Peoria is certainly a great deal better than it was prior to that time. The water is clearer in color and does not get so low at low water, and therefore does not have disagreeable features of the former low stage of water. Below Peoria since 1900 the waters still show the effect of the offal from the factories, but not to the same extent as before, because of the greater volume of water, and I find the odor not nearly so apparent as it formerly was. Before 1900 the use of the river for pleasure craft was almost entirely given up during low stage of water. Since that time there is continual use of the river by a great many people for pleasure purposes—using house boats for summer residences. A great many people also row for pleasure." (3591-2.)

Bradley B. Hawley testified as follows:

"My business is steamboating and boating.

"Am captain of the 'City of Henry.' I have been steamboating and working on the Illinois River about 43 years. Before the opening of the Canal the quality of the water in the Illinois River was always better above Peoria than it was below Peoria, but in low water, it was a prettly sluggish current and the water was pretty bad—very bad water between Peoria and La Salle before the opening of the Canal. In the spring we didn't notice much difference but in the hot weather or low water, and dry times, the water was what we called pretty bad, that is, it moved slowly in the river. There would be an odor at times, especially in the morning. There was a good deal of green stuff floating on top of the water. Below Peoria the opening of the Canal, it was pretty bad, caused by the sewage from Peoria.

"The water above Peoria was a good deal better than it was below Peoria at the same time. Of course we think the sewage and polluting matter comes out of the cattle pens, but we never went to see about it. The most we noticed is between the T., P. & O. bridge where spouts lead into the river and where sugar mills and still houses are located. The gas works put out a lot of bad water there. The manure that we saw in the river was in front of those spouts that run out that are supposed to be from still houses. Last summer they hired us to go in there and kick it out in the river and get the stuff away from the end of the spout.

"It was in the summer after the water went down. It was in June or July. There would be as much as half an acre of it. After you get down below the bridge at Peoria, say a mile below the bridge, the water begins to get thick and full of something. It is a kind of thick, dirty water.

"Since the opening of the Canal, there is more of a current going and the water is what I should call more pure

than it was before. It looks more pure and clearer to me. Below Peoria it is the same as it was before, only it isn't so bad. It doesn't look so bad to me. The water in Lake Peoria, immediately above Peoria, looks more pure to me than it was when this green scum settled on it. The water above Peoria never was very muddy, that is, after it got below this scum that used to float on it in low water. The Peoria Lake water was what you might call bad water, except when this scum was floating over the top. In my opinion, the water of Lake Peoria is better and clearer now than it was before the opening of the Canal. Oftentimes we noticed a substance that looked like this stuff that passes out of the cattle pens below Peoria. It raises up in a great large piece that comes up with bubbles. It seems to come from the bottom of the river.

"Before the opening of the Canal if you cut a hole in the ice, the water smelled bad." (3379-83.)

L. S. McCulley testified as follows:

"Am an engineer and reside at Chillicothe. Have been an engineer on boats running on the Illinois river.

"Have been engineer at this Turner-Hudnett Company elevator for four years. When running boats on the Illinois River I used Illinois River water in the boilers. I have run from Copperas Creek to Henry and above. I was an engineer between those points upon boats both before and after the opening of the Canal. Below Peoria, before the opening of the Canal, the water foamed slightly and at times strong in the boilers. Closer to Peoria it foamed stronger than it did below. Pollution causes water in a boiler to foam. Below Peoria there was a smell to the steam that escaped from the boiler. It was a real strong odor of decayed matter. Since the opening of the Canal below Peoria the water has been quite clear; it hasn't foamed any. Before the opening

of the Canal above Peoria the water in the boilers foamed and there was odor to the steam.

"Since the opening the action of the water in the boilers here has been better; no foaming and no odor excepting that that comes from natural clear water. Since the opening, the water from above Peoria is the best a little, for steaming purposes. Before the opening of the Canal the water above Peoria was the better water for steaming purposes. Before the opening of the Canal the water for steaming purposes taken at this point foamed in the boilers and there was an odor to the steam. The odor was stronger in summer. Since the opening the water has been better, not as much lime or scale. There was a great deal of lime and scale in the water used below Peoria. Since the opening of the Canal not as much." (3432-4.)

S. P. Bartlett, whose duties as fish commissioner are such as to require him to become familiar with the conditions in the Illinois River all along its course testified as follows:

"Reside at Quincy and am Field Superintendent of United States Fish Commission, which position I have occupied for about 31 years. I am also a member of the Board of State Fish Commissioners and have served consecutively for 24 years.

"We have no hatcheries in Illinois, but we have retaining ponds at Meredosia. As a member of the State Fish Commission, my duties are the collection and distribution of indigenous fish and the management of the Commission's boats.

"In the employ of the Fish Commission, in the summer, there are about 150 people. I have been intimately associated with the Illinois River for over thirty years. Prior to the opening of the Canal in the early spring, the current at times would reach a mile or a mile and a half an hour. Later in the season when the water was lower, it has been frequently impossible to tell which way the current was going. It was

very sluggish and very slow. There are four dams in the Illinois River.

"In low water the effect of those dams would be to make the current of the river very slow. At high water, there would be no perceptible effect. The effect would also be to make slack water at a very low stage of water. Prior to the opening of the Canal, the river between La Salle and Henry dam was about on the average of river water. There was an odor more or less, as I remember it at low water times. It came from decaying vegetation and refuse matter dumped into it. I have seen the stage of river so low in the Illinois River during the winter season that the fish would perish under the ice. The condition of the fish between La Salle and Henry would vary with the different seasons. I have known fish to die there previous to the opening of the Canal. Fish are very susceptible to the condition of the water in which they live. It is nothing uncommon to find fish taking on a coloration from the character of the water they are in. The temperature and condition of the water have a material effect on the coloration of the fish.

"The strong fish always have a dark bright color. Judging from personal observation, and going over it frequently, my judgment would be that the water of the Illinois River above Henry dam shows a decided improvement in every way since the opening of the Canal.

"Since the opening of the Canal my observation has been that the water is frequently better and clearer between Henry and Peoria Narrows. The fish seem to be in good merchantable condition. At Peoria there are foreign substances deposited in the river from all sources. The sewage is very large. The refuse from the gas houses and distilleries and glucose factories is immense.

"I have noticed this foreign matter in large quantities be-

low Peoria. I met this condition of pollution frequently as far down as Havana in limited quantities, of course.

"There are a number of lakes below Peoria and above Copperas Creek dam which have natural connections with the river. Spring Lake is the one containing the greatest area. Prior to the opening of the Canal this lake was affected very materially by the cast off matter from Peoria and Pekin. If the water was rising, this stuff would break off from the shores very easily and was taken in great quantities into this lake. In fact I have seen it in sufficient bulk, in the Canal leading into the lake, to prevent our going in with boats. We had to break it up before we could get by. It floats off into the lake and with other impurities makes the lake very foul at times. (Witness states bad condition of Spring Lake a number of years ago when an investigation was made thereof.)

"The artificial Canal leading into Spring Lake is about four miles above Copperas Creek dam.

"Since the opening of the Canal I have made inquiries into the condition of Spring Lake, both above and below the revetment where this pollution entered the same.

"About ten years ago, some of the black bass I took from this river, upon post-morten examination disclosed that all of the digestive organs of the fish had been absolutely dissolved. The men sickened in making a haul of fish at that place. Since the opening of the Canal I do not believe there has been a season when any dead fish have been found in the lake. The water is very much clearer and an examination of the bottom, while it shows quite a deposit, is very slight as compared to the season of which I spoke. Before the opening of the Canal, between Copperas Creek and La Grange there would be a great deal of vegetable growth in the water and in a good many places fish would die from the high temperature and the decaying vegetable matter.

"Since the opening of the Canal there has been a much

greater volume of water and the water has been much better and there has been a great decrease of various kinds of vegetation. The best evidence that we have of the increased betterment of the water at points below Copperas Creek is the fact that there are more black bass in the river this year than I have ever known. Before the opening of the Canal the water between La Grange and Kampsville, except in very low water, was classed as fairly good. Before the opening of the Canal the lakes and bayous between La Grange and Kampsville varied according to the seasons. Some seasons the water became very bad from decaying vegetation and very foul and very destructive to fish life. Since the opening of the Canal the condition has been in my opinion good.

"The fish between La Grange and Kampsville, since the opening of the canal, have been in fine condition. As I stated a moment ago, there are more black bass, which are inhabitants as a matter of choice of only clear water. The ponds and bayous have been higher and the fish propagate better. Between La Salle and Peoria, since the opening of the Canal the character of the water is improved, until we get to Peoria Lake we get a practically good water. Between Peoria and Copperas Creek the water improves as you get close to Copperas Creek. The water below Peoria from Peoria to Copperas Creek dam is very considerably worse than that in Lake Peoria. Except under extraordinary conditions, there is very rarely a better body of water found anywhere than in Peoria Lake. The water gets better all the time as you go farther down the river.

"A man does not have to be an expert to notice that.

"I have a very large acquaintance with fishermen from La Salle to Grafton. There are from 2,500 to 3,500 people directly interested in fishing themselves, which does not include the helpers. All told there would be 5,000 people—this would be a fair estimate. Before the opening of the Canal we had

a great deal of sickness among our men. Not much typhoid but a great deal of low grade fever. I was going to say as a physician—but from what knowledge I have, this was owing to the very bad stage of the water during low water. I have never practiced medicine. I was educated and graduated as a physician.

"Since the opening of the Canal my observation has been that there has been a very great decrease in typhoid and intestinal diseases among the people engaged in the fishing industry on the Illinois River.

"My work carries me to almost every town along the Illinois River and in my talk over semi-professional matters with physicians, every one of them has commented on the decrease of typhoid and malarial fevers during the last two or three years.

"The health of my own men has been very vastly improved.

"From all sources of information I should say that the health of the fishermen generally has been a great deal better. In my opinion there are more than 5,000 people in tents and flat boats or in house boats on the sloughs and bayous, bays and lakes connected with the Illinois River. In my opinion the health of that class of the population has improved since the opening of the Canal. The towns along the Illinois River are much sought after as resorts for pleasure fishing.

"The interest in fishing and sport on the Illinois River has been great and almost every available lake on the river of any size, has been taken for a pleasure resort. They build either club houses on the bank or house boats. The Illinois River is very peculiar in its formation, in that it has flat shores on both sides of the river. These bottoms extending from three to fifteen miles in width and filled almost in every case, with lakes and sloughs, aside from the river itself. As the fall is only a half inch to the mile, the overflows are very frequent

and the lakes fill up and evaporate again several times during a season, during the dry seasons. The course of the river is inclined to be free from bars and of a very even depth. The land on both sides of course, on account of frequent overflows, is very much as nature left it. The river in extreme high water will sometimes be 12 to 15 miles wide.

"The country adjoining the Illinois River is devoted to agriculture. Domestic animals, adjoining the river are accustomed to drink these waters. The lowlands in some places are used for pastures during low water.

"Cattle are brought from a distance in the seasons of low water for the purpose of being pastured on the lowlands of the Illinois bottoms. I have never heard of anthrax among cattle along the Illinois River, nor have I ever heard of any diseases among cattle drinking the Illinois River water, which were attributed to the drinking of the water of the river. The increase in fish in the Illinois River has been very great in the last three years. In 1901 the report of the Fishermen's Association—an organization of about 1,000 men on the Illinois River, gives a total of eighteen million pounds of coarse fish caught, with quite a per cent. of fine fish, as well." (3619-40.)

Isaac Taylor, testified as follows:

"I reside in Peoria. Have been in the real estate and loan business 33 years. Have been Canal Commissioner and also on special commission to inspect the Chicago Drainage Canal. I have been familiar with the Illinois River from 1850 to the present time. Am chairman of the Illinois Valley Association. I was one of the committee appointed by Governor Tanner to inspect the Drainage Canal and report to him as provided by law under which the Drainage Canal was constructed. Our duties were to inspect the Drainage Canal and ascertain if the Sanitary District had complied with the law in the construction of the Canal. We employed an engineer

in chief and made complete surveys and a full investigation following the requirements of the law, and found that the law had been complied with.

"As a member of the Valley Association, I made an inspection of the Illinois River during the summer and fall of 1901 and have made frequent inspection of the river since that time. This was for the purpose of ascertaining the character of the water as compared with the water before the Chicago Drainage Canal was opened, and also to make some estimate of the amount of the flow. I will add to that the effect of the flow upon the Illinois River. Before the opening of the Canal the water in the Illinois River was low, bad looking and bad smelling. It was more noticeable from La Salle to Henry and it was also noticeable from Henry to Peoria. From Peoria down it was in bad condition.

"When the water was low from Peoria down to Copperas Creek, the water was of a bad character with considerable sediment in it. That condition obtained to a certain extent all the way down to Copperas Creek. The turning in of the waters of Lake Michigan through the Drainage Canal has made the water very much clearer and very much better. The water above Peoria in Lake Peoria at the present time is in very good condition. There is no odor discernible. As to the condition below Peoria, I could not testify so definitely in regard to that, only that the water has a dark appearance; it is darker than above Peoria. The condition below Peoria is much better to-day than it was before the opening of the Canal. The river has a larger flow of water. I estimate it from two and a half to three feet deeper, the water is clearer and better in every way for navigation and sanitary purposes." (3657.)

VOLUME NINE, BEING RE-PRODUCTION OF COMPLAINANT'S EXHIBITS.

Under this heading we will briefly refer to the volume of exhibits which are made a part of this record.

Exhibits 1 to 9 relating to bacteriological examinations, are answered beginning on page 61 of this argument.

Exhibit 1 is a graphic illustration of the number of bacteria found in the waters referred to and shows in a graphic way the contention made by us on page 71 of this argument.

Exhibit 10 is answered in this argument under the heading of "Typhoid Fever" beginning on page 311. The court will remember in this connection that the basis of this chart is the typhoid statistics of the Health Department of St. Louis which we show are incorrect and for that reason Exhibit 10 should have no weight with the court.

Exhibits 11 and 12 are answered in this argument beginning on page 61 thereof.

What is here said in regard to Exhibit 10 applies also to Exhibit 22.

Exhibits 23 to 33 are answered in this argument on page 95. In this connection we might say that the condition at the St. Louis Reservoir, Chain of Rocks, etc., is immaterial so far as this case is concerned, as it is shown that the opening of the Canal has not injured the sanitary quality of the Illinois River at Grafton, the point where it empties into the Mississippi River. If the sanitary quality of the Illinois River has been improved by the opening of the Canal, which we contend is true, then whatever impurities are found at the St. Louis Intake, Reservoir or Chain of Rocks, must come from the Mississippi and Missouri Rivers independent of the Illinois River.

Exhibits 33 and 34 are answered beginning on page 344 of this argument.

Exhibits 35, 6, 7, 8 and 9 are answered beginning on page 95 of this argument.

Exhibits 40-1-2-3 are answered beginning on page 202 of this argument.

Exhibits 46 and 47 are answered on page 103.

Exhibits 48-9-50-1 are answered beginning on page 125.

Exhibits 52-3-4-5-6-7-8-9 are answered beginning on page 95 and also page 344.

Exhibit 55 makes a comparison of the Mississippi River at Grafton with the Illinois River at Peoria. This is of no value to the court for the reason that the water must travel 160 miles from Peoria to Grafton before it reaches the Mississippi River. The water at Peoria in the Illinois River does not mix with the water of the Mississippi River. During the flow of 160 miles necessary before it reaches the Mississippi River, many changes take place. It will thus be seen that this is an unfair and incorrect comparison.

Exhibit 60 is answered on pages 95, and 344.

Exhibit 61 showing the amount of removal of suspended matter in the reservoirs of St. Louis, is the statement, "The above curves show the enormous removal of suspended matter in the subsiding reservoirs. * * * Which shows that there is a great, although by no means sufficient purification effected before the water reaches the consumers." Unless the impurities at the Intake are caused by Chicago sewage, this table or exhibit is of no value. It simply shows, if correct, that the apparatus used by St. Louis for purifying its water supply is inadequate for the purposes for which it was intended, which is no fault of defendants.

Exhibits 62-3-4-5 show the chemical condition of the waters of the old Illinois & Michigan Canal, Desplaines River and Drainage Canal. Whether these waters are polluted or not

has no bearing on this case. These waters do not flow directly into the Mississippi River—they flow into the Illinois River which then travels nearly 300 miles before it reaches the Mississippi, and by which time we have shown it is purified.

Exhibit 66 is answered beginning on page 344.

Exhibit 67 is answered beginning on page 95 and also page 344.

Exhibit 68 is answered beginning on page 344.

Exhibit 69 is intended to show the inferior character in port of the Mississippi River at Hartford. There is nothing on this chart showing that the Illinois River contributes to that condition and we have shown beginning on page 344 that such is not the case.

CONCLUSION.

We submit that taking the complainant's evidence by itself, they have failed to make such a case as would entitle them to the relief asked for. The evidence of complainant is not "determinate and satisfactory" and is, in itself, conflicting, and for that reason does not come within the rule laid down by this Court.

On the other hand, the scientific testimony introduced by defendants shows conclusively that prior to the opening of the Canal and subsequent thereto, all trace of sewage has disappeared in the Illinois River by the time it has reached Averyville, which is located immediately above Peoria the water again becomes polluted by the sewage and refuse from Peoria and Pekin, but purifies itself a second time before it reaches Grafton, which is located on the Illionis River at its mouth.

The scientific evidence further shows that since the opening of the Canal, the same degree of purification takes place in the Illinois River and that the water at Averyville and Graf

ton, through the influence of the dilution of the Illinois River water with that of Lake Michigan, is in a better sanitary condition than it was prior to the opening of the Canal.

Three separate scientific methods were used, chemical, bacteriological, and bacterio-chemic, to determine the sanitary condition of the water. These scientific demonstrations made by the defendants, all concur, agree and corroborate each other. They all show that the sanitary condition of the water of the Illinois River has been improved by the opening of the Drainage Canal. They also show that pathogenic germs entering the sewers of Chicago are destroyed before they reach Averyville; indeed they show that by the time the water reaches Ottawa, 81 miles from Chicago, practically no indications of Chicago sewage is present and by the time Averyville is reached, which is about 160 miles from Chicago, the water of the Illinois River is purer and better than it was before the opening of the Canal.

The scientific evidence also shows that the most elaborate experiments on record were conducted by learned bacteriologists to determine the longevity of the typhoid bacillus in the waters of the Chicago River, Drainage Canal and Illinois River. These experiments conformed more to natural conditions than any that have ever been made by scientists heretofore. These experiments show conclusively that a typhoid bacilli, which is admitted by complainants to be the hardiest *pathogenic* germ that exists in sewage, dies long before Averyville is reached in the Illinois River, and further show that it is impossible for a typhoid bacillus introduced in the sewers at Chicago to reach Grafton at the mouth of the Illinois River.

The evidence of three hundred or more lay witnesses was taken along the Illinois River. This lay testimony shows that the water is better, clearer and purer since the opening of the Canal.

The lay testimony corroborates the scientific testimony in every particular and is uncontradicted by a single witness introduced by complainant.

We respectfully submit to the consideration of the Court that the burden of proof being upon complainant, it was necessary for them to affirmatively show by determinate and satisfactory evidence that the opening of the Drainage Canal resulted in injury to the complainant. This we submit complainant has totally failed to do, as is shown by their lack of positive testimony.

On the other hand defendants have conclusively and affirmatively shown not only by every means known to the scientific world, but by the testimony of over three hundred lay witnesses, that the opening of the Chicago Drainage Canal has resulted in an improvement of the sanitary condition of the Illinois River.

We respectfully submit that the issues should be found for the defendant.

Respectfully submitted,

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IN THE

SUPREME COURT

OF THE UNITED STATES

October Term, A. D. 1905

STATE OF MISSOURI

vs.

STATE OF ILLINOIS AND SANITARY DISTRICT OF CHICAGO

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ERRATA.

On page 95 of abstract, marginal page 644 should be 649.
On page 181 of abstract, marginal page 1193 should be 1191.
On page 317 of abstract, marginal page 1855 should be 1885.
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IN THE

Supreme Court of the United States.

THE STATE OF MISSOURI
vs.
THE STATE OF ILLINOIS
and
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IN THE

Supreme Court of the United States.

THE STATE OF MISSOURI
vs.
THE STATE OF ILLINOIS
and
THE SANITARY DISTRICT OF CHICAGO.

Original
Docket No. 4.

Before
FRANK S. BRIGHT,
Commissioner of the Supreme Court of the United States.

Testimony begun at the City Hall of St. Louis, Missouri, February 17, 1903, at 10 o'clock a. m., pursuant to an order heretofore entered in said cause.

Present:

THE COMMISSIONER,
ATTORNEY GENERAL EDWARD C. CROW,
CHARLES W. BATES, Esq., and
S. B. JEFFRIES, Esq.,
Appearing in behalf of the complainant.
ATTORNEY GENERAL H. J. HAMLIN,
Appearing in behalf of the State of Illinois.
JAMES TODD, Esq.,
JUDGE WILLIAM M. SPRINGER and
J. G. DRENNAN, Esq.,
Appearing in behalf of the Sanitary District of Chicago.

Agreement.

All of these samples that were collected at points where laboratories were established. Now in St. Louis a room was secured from the water commissioner at the chain of rocks pumping house, and the samples were collected in the river for the Chicago and St. Louis experts at the same time and place. A Chicago and a St. Louis bacteriologist plated the samples in this same room so that the samples were plated immediately when brought ashore.

Q. Now, what were the facilities furnished by the city at that time?

A. The city furnished a good room and it was kept warm. I believe Chicago paid for some of that heat. Anyhow, it was a convenient place for the men to do their plating. The plates were then brought to the laboratories of both parties, brought to 1141 Market street by Mr. Damon, who did our plating, and to the Chicago
218 Laboratory by the Chicago expert, located somewhere on Locust street, both going in and out together to the chain of rocks.

Q. Do you know that they collected the samples at the same place?

A. I know they were collected because these men went out together.

He (Mr. Randolph) and I together selected these points of
214 collection at Lockport and Joliet, and he of course knows the typography of the country better than I.

There was no objection. There was an agreement that we should collect samples at the same place, and at the same time, but that if any special work was to be carried out we were to do it independently of the other.

Q. With whom did you make that agreement?

A. We made that agreement, I think it was with Mr. Randolph and the Board of Trustees, but that was made through Mr. Schumacher. He was then the City Counsellor, and that let-
911 ter is in the files of the Department. The idea was this, that we didn't care to stop at any minute and notify the Chicago bacteriologist that we wanted to carry out some special work.

AVERAGES.

ATTORNEY GENERAL CROW: In the first place, though, this test was made in the same manner as the other was that you have described weekly from averages?

A. Yes.

354 Q. An average made from the daily examinations?

A. Yes.

Q. Now, how did you ascertain the results after you had counted them? Did you always get the same?

A. The results were averaged.

Q. Well, how? Explain how you averaged them.

A. Each would refer to his own analysis, to his own results. The figures obtained from the similar samples were averaged.

Q. Is that in accordance with the proper way to do that bacteriologically, where the two men work on the same samples?

A. It is the safer way. It is a check. One individual checks the work of another by this method.

Q. Well, is that the way, scientifically, this class of ex-
572 aminations are made, bacteriologically, where two men work on the same samples?

A. Yes, sir.

BACTERIOLOGY.

Potability.

Q. Is there any means now known of obtaining absolute proof of the hygienic quality of water supplies?

A. Well, bacteriology will indicate the presence or absence of bacteria.

Q. Is that sufficient to determine the potability of the water-supply itself?

A. Yes, sir, it was used by the German Government.

890 Q. It may be sufficient?

A. Yes, sir.

Q. In order to obtain a perfect or an approximately perfect knowledge of the bacterial condition of running water, would it be necessary to take samples every day in the year and under precisely similar conditions for those days in order to make your cal-
891 culations reliable?

A. Yes, sir, that is what we did.

Rivers.

Q. Then isn't it true that the condition, bacterially considered, of the Illinois, the Mississippi and Missouri Rivers at the places where you have taken samples of water, are very similar to the conditions of rivers found, of similar size of rivers, in this country and in Europe?

A. Yes, sir.

Q. Isn't it true of all the periods to which you have referred as the first, second and third period of our investigation here?

A. Yes, sir.

Q. So that you are not surprised to find, then, in all these waters, a large number of bacteria at different times?

A. No, sir.

Q. Are the rivers generally, in this country and in Europe, in such a condition as to render them unfit for water-supply for cities without some kind of sedimentation or filtration?

A. Yes, sir.

Q. That is they are unfit?

A. Yes, sir, as a general rule.

Q. That applies to all the rivers to which you have referred in your examination here?

A. Yes, sir.

Q. As a bacteriologist then, you would not recommend supplying cities with water taken from the running streams of this country without some system of sedimentation or filtration being adopted for the purpose of removing bacteria?

A. No, sir, I wouldn't.

Q. That opinion applies to all the rivers of which you have spoken in this examination, does it not?

895–896 A. Yes, sir, because all these rivers have sewage discharged into them.

Q. So that bacteriologists, in ascertaining the cause of typhoid epidemics, have not, up to this time, definitely located the cause of the infection at a greater distance than between Detroit and Port Huron?

A. Yes, sir, simply because, as I said this morning, it is impossible even if typhoid bacilli were found at the place of entrance of sewage, and these typhoid bacilli found in the water below it, it could not be proven that they came from this particular place, because the bacilli is not labeled, has no sign or mark on it by which it could be distinguished from a typhoid germ coming from any other source.

Q. Then there is no ascertained cases of whether infection
904 was brought further than the case you have just mentioned?
A. I know of none.

930 Saprophytes and Parasites.

Sewage Pollution.

Q. What is the one thing, aside from the aesthetic standpoint, that renders sewage and polluted waters a warning against the use of the same from a medical, bacteriological and chemical standpoint?

A. It is the evidence of sewage pollution.

Q. The evidence of it, but what is the one thing in sewage polluted water or connected with sewage polluted water that warns the sanitarian that it is not fit to use?

A. It is the pathogenic germ.

Q. I will get you to state as a bacteriologist if there is an established connection between sewage and pathogenic germs that convey disease?

A. Yes, sir. Where sewage is found in a stream it is presumed that pathogenic bacteria may be there also, because sewage polluted water contains the discharges of human beings, and if there be typhoid or other diseases among them like diseases will follow in those drinking the water.

Q. Aside from the repulsiveness of drinking sewage that comes from aesthetic reasons, the real danger in sewage comes from the germs?

A. Yes, sir.

Q. Aside from the finding of bacteria that usually accompanies
954 sewage, the ordinary scientific test of whether water contains sewage pollution isa chemical test?

A. Yes, sir.

Potability.

Q. That is used in connection with the bacteriological test to determine the potability of water?

A. Yes, sir. There are three tests, the microscopic examination, the bacterial examination and the chemical examination. They must be combined.

Q. It takes the three to determine the potability of a water
955 supply?

A. Yes, sir.

CENTIMETER.

Cubic Centimeter.

909

Coli.

Q. What do you call the bacteria that is found in the water and that is found in the water fed by sewage and is found in the stomach of animals, including man, or rather in the intestinal canal?

A. The one that has been looked upon as the index of fecal pollution—that one is called bacilli coli communis.

25 Q. I will ask you to state whether there is any other bacilli that are found in running streams that are an indication also of sewage in water?

A. There are several, but there really is no good index. There are micro organisms that are found in sewage steadily; wherever sewage is present they are present in large numbers, but a true index of the fecal pollution, I don't know a single one.

Q. Now, do you mean to include in that statement the bacilli that we have been talking about?

A. Yes, sir. That is previous to our work upon the intestinal contents of fishes these micro-organisms were really looked upon and I believe it is still held by Professor Jordan, looked upon as an index to fecal pollution, but our own experience robbed it of that dignity.

Q. Why is that?

A. Why, if it is found in a stream steadily and we know that there are fish in the stream at the same time which have it in their intestinal contents, and are discharging it from their intestines, then the bacilli coli communis found in that particular water may be either from sewage, from man or from animals or fish.

69–70 Coli-Determinations.

Illinois River at Grafton, Mississippi River at Grafton, and Mississippi River at Fort Bellefontaine for the third period, October and November, 1901, made jointly with the Sanitary District.

50 Illinois River at Grafton.

Number of determinations made October and November.

246 Coli present 21 times, absent 29 times.

245 For October coli was found 53.6 per cent., of the cases for November 29.17%, an average of 45%, which if properly calculated would be 41.3%.

Mississippi River above Grafton, 55 coli-determinations; present

28 times, absent 27 times. Percentage present for October
248-249 33.33%, for November 62.50%; for two months, average 47%.

Missouri River at Fort Bellefontaine. Coli-determinations, 51; present 44, absent 7.

255–256 During the third period the percentage of coli bacilli at Fort Bellefontaine in the Missouri River October, 1901, is 92.6%; in November, 1901, 80%; the average of this is
276 86.2%.*

753 Tables of deaths per 100,000 in cities of Europe.

958–959 Table of deaths in Chicago.

419–432 Table of deaths and cases in St. Louis.

EPIDEMICS.

463 The epidemic of Lausen, Switzerland.

466 Epidemic of Plymouth, Pa.

734 Epidemic in St. Louis in 1899.

Q. Do you know the occasion of that increase?

A. In 1899?

Q. Yes, in 1899.

A. I have looked over the health statistics. In 1899 we have a remarkable number of cases; in November 488 cases reported and thirty-one deaths and in December 116 cases and twenty deaths, which makes the great increase in this year. It was ascertained at this time, in fact I saw the men at work. The river was so low in 1899 that it was feared by the water commissioner that the lowest gates in the intake tower would not be low enough to admit enough water for the pumps, so a coffer-dam was built about the intake, and men put at work breaking a hole through the tower for the purpose of putting a gate in.

Q. Now, from a bacteriological and sanitary standpoint, what was the effect of that stirring up of the silt and mud in the bottom of the river where it had settled at the bottom of the intake tower since it had been put in there?

A. The result would be, of course, to stir up any bacteria—any typhoid or pathogenic bacteria in the water there.

Q. From a scientific standpoint, as a bacteriologist, and by

*The relative pollutions of the Missouri, Mississippi and Illinois Rivers, as disclosed by these coli determinations, are as 86.2 per cent. Missouri, 47 per cent. Mississippi, and 41 per cent. Illinois, which plainly shows that the Missouri is more polluted than the Mississippi and the Mississippi more polluted than the Illinois.

gienist, then, do you think that would account for the increase in the death rate?

A. Well, if it were due simply to the stirring up of the mud there would be a suspicion that that was the cause, but I have not sufficient data to enable me to draw the conclusion that that was really the cause, although the cause for that particular flare in November has been ascribed to the work that was going on in October in that tower.

Q. Do you know whether or not at that time there was any dredging going on at Kampsville in the Illinois River?

A. I know there were dredges at work in the Illinois River
764-765 below Kampsville.

TYPHOID FEVER IN ST. LOUIS IN MARCH, 1900.

Q. What was the difference in the appearance of the water taken at the tower and the water on the Illinois and Missouri shore?

A. The water on the Missouri shore was fairly clear, the samples on the Illinois shore was dark, black. The sample at the intake shore about an equal mixture of the two waters, and this is demonstrated in the examination.

Q. What period was this?

A. That was in February, from the 8th until the 20th, 1900, I think.

Q. What relation did these dates have to the epidemic of typhoid that ensued in the spring of 1900 that you have heretofore testified about?

A. Within an incubation period, the typhoid death rate ran up rapidly in this town in March. Samples were collected in February and in March, 117 cases, and sixteen deaths by typhoid occurred in St. Louis, a phenomena that never had occurred previously, and I believe has not since. * * * No such flare of typhoid in March has ever been recorded in the history of St. Louis as followed
837 the mixture of these dirty waters at the intake.

Detroit Epidemic.

Q. What percentage of accredited cases that are reported in the book show the source of typhoid fever from water pollution to be exceeding fifty miles?

A. Well, I cannot say that definitely, and it would be an extremely difficult thing to do on account of the complexity of modern life.

Q. I am asking about the cases reported that have come within your knowledge or reading.

A. I said it would be a very small percentage of reported
867 typhoid epidemics.

Q. Now name one, if you have one in mind.

A. I have one in mind.

Q. Where was that?

A. Dredging at St. Clair.

Q. How?

A. Dredging of the St. Clair River and the typhoid fever epidemic followed in Detroit. That has been reported by Dr. Williams.

Q. Doctor, that was a case when the river was being dredged?

A. It is a case. You asked me for typhoid fever epidemic. There were typhoid fever cases, up the river above that. Typhoid fever discharges went into the river. They dredged into the silt and sludge and slime at the mouth of the Wolf River. This sludge was stirred up some time afterwards and carried across Lake St.
868 Clair into the water supply.

Q. Then wouldn't you say that 95 per cent. of the reported cases of typhoid fever epidemics or a large increase of typhoid fever from water pollution has been shown to be less than fifty miles?

A. Simply because of the facilities?

Q. Well, now, answer the question.

869 A. Yes, sir.

Q. Are not many known cases of typhoid epidemic produced by the spring floods washing the dejecta into the river which has been deposited during the winter season and not from the sewage of cities?

A. There are not many cases of that kind. We had a remarkable case, which I mentioned this morning, at Detroit, in which a mass of filth and sewage which had collected at the mouth of Wolf River was cleared away and carried across Lake St. Clair into the
897 water supply of Detroit, causing typhoid fever. * * *

Q. Have you any information from your own investigations or from the books of a typhoid epidemic being caused, the cause having been ascertained definitely, by a pollution which occurred at a remote place from where the epidemic occurred, say more than fifty miles?

A. Well, we had that one at Detroit, caused by the dredging of the St. Clair River. The typhoid bacilli came from Port Huron which, I believe, is sixty-seven miles away, and they were carried

across quite a large lake, Lake St. Clair, and into the water
905 supply.

Q. General Hamlin asked you a question yesterday, if it was not a fact that the recorded cases showed fifty miles or less as the distance that bacilli traveled through water and produced disease. I will ask you to show why the records show that to be, more or less the fact.

A. Because of the difficulty of tracing the micro-organisms under the complex conditions of modern life. IF IT WERE AN OPEN RIVER IN WHICH THE TYPHOID BACILLI WERE UNDER CONSIDERATION, THE POSSIBILITY OF THE RIVER BEING INFECTED FROM CASES ON ITS BANKS OR OTHER EXTRANEOUS SOURCES MUST BE WEIGHED, SO THAT TO TRACE AN EPIDEMIC MORE THAN FIFTY MILES IS AN EXTREMELY DIFFICULT THING TO DO, EXCEPT UNDER SUCH CONDITIONS AS THAT OF THE ST. CLAIR LAKE, DETROIT, EPIDEMIC. If the river were covered with a tunnel, or running through a tunnel, such as the Croton aqueduct, for a number of miles, then we could say absolutely, for if a typhoid epidemic were to occur in New York, we would feel perfectly confident that no extraneous case of sewage discharge came into the tunnel from any other source than where the aqueduct opened on the water-shed. In the Detroit case we had a remarkable instance. Here we had a bed of sewage in a river which had laid there for years, and it was suddenly disturbed by dredging, and was carried across a lake. It was practically as if in a tunnel, because the sides of the lake were so far away that one or more cases which might have discharged feces on the periphery of the lake could have no effect. If the material had been carried straight away in a tunnel it could not have been
carried more directly to Detroit than it was. That this was
932 the cause of the outbreak of typhoid fever in Detroit, Professor Williams has declared on and so reported.

EPIDEMIOLOGY.

Q. As a practical bacteriologist, I will ask you, in your judgment, if typhoid bacilli coming from the outfalls of the Chicago sewers into the Chicago River, and carried into the canal, could come into the intake tower of the St. Louis waterworks, still retaining its vitality, * * * considering your knowledge of the flow?

A. By basing my conclusions upon the experiments that I have carried out, and showing that the Mississippi and Illinois Rivers waters come into the intake of the St. Louis waterworks, I am inclined to

believe it is highly probable that a typhoid bacillus can live and be carried by water carriage from the Chicago sewers into the intake of the St. Louis waterworks, especially in high water conditions
788 in the Illinois River.

Q. Doctor, assuming that it requires the water seventeen days to run from the sewage openings at Chicago down the river to the canal, the canal to the Desplaines, the Desplaines to the Illinois, and thence to the Mississippi, the intake at the chain of rocks, and thence into the reservoir, when in two days thereafter it is distributed and used by the people of St. Louis, what would you say with reference to typhoid bacilli discharged into the Chicago drainage canal through the sewage system of Chicago, finding its way into water distributed to the people of St. Louis, as above described, and be sufficiently vitalized to produce disease, and taking into consideration your actual experiments with the typhoid bacillus, in connection with the water in the various streams through which it would run?

A. Now, the time consumed, then, in traveling from Chicago, of the sewage would be seventeen days, in the river to the intake; from my experiments that typhoid bacilli discharged by the sewage system of Chicago into the drainage canal could live—retain its vitality the while, enter the intake of the St. Louis waterworks, and be distributed to a user of the water, sufficiently vitalized to cause
808 disease in a susceptible individual.

Q. Doctor, I understand you to state that the primary cause from the disappearance or elimination for the bacteria known as typhoid bacillus is due to dilution and sedimentation?

A. Yes, sir.

Q. What other causes do you give besides these two?
848 A. I regard these two as the principal ones.

Q. Well, now, how is the Missouri River water?

A. It is a turbid water.

Q. Then the effect of the sunlight as an element of the disappearance of the typhoid bacillus would be less on the Missouri River than it would be on the other two rivers in your judgment?
851

A. Yes, sir.

A. If there was a case of typhoid fever on any of the tributaries of the Illinois River which would pass its dejecta into the Illinois River through any of its tributaries, you couldn't tell—it would not be labeled.

Q. How?

A. It would not be labeled.

Q. Wait a minute; I have not finished the question. You could not tell how that bacillus originated or any typhoid bacillus, assuming that one would come this distance—you couldn't tell whether it came from the sewage of Chicago or came from some tributary of the Illinois, could you?

A. No, sir; not even if I found it in the water.

Q. You couldn't tell.

A. No, sir.

Q. They have—it would have no distinction that made a Springfield typhoid bacillus different from that of Chicago? It would not be red-headed or ring-tailed?

A. No, sir; nor bald. * * * The chances are that the bacillus traveling from Chicago to St. Louis would lose its virulence sooner than the one that had traveled only a few miles.

Q. The nearer you would be to the consumer, the more likely would be the bacillus to be carried?

A. Yes; if you had 100 men with typhoid fever discharging sewage into the river at the mouth of the Illinois River at Grafton, the danger to St. Louis would be much greater than if 100 men were discharging their typhoid fever discharges into the Illinois River at Lockport from the drainage canal.

Q. That is what I desire to bring out. Pursuing that suggestion further, suppose that there should have been twenty persons who died of typhoid fever, within, we will say, the year 1900, or 1901, or 1902—yes. And that there was a corresponding number of persons in the same vicinity in the village who recovered from the disease, and the dejecta of all persons who died and those who lived were deposited into the Illinois River, say, at the mouth of the Illinois River at Grafton, what would you say as to the probability of such a deposit producing typhoid fever in St. Louis?

A. It comes within—it is probable that if the micro-organism were carried into the intake from people sick of the disease that a person in St. Louis drinking the water or taking the bacillus into their intestinal canal would contract the disease, provided they had not been immunized.

Q. Would it not be a dangerous proximity for so many cases of typhoid patients whose dejecta might be thrown into the river so near the intake?

A. That would be forty people in the whole year. That would be four people a day constantly discharging their dejecta into the stream during the whole year.

Q. Yes?

A. There is a possibility of such bacteria being carried into the St. Louis intake and producing disease in St. Louis.

Q. Would it not there be more than a possibility? Would it not be a dangerous proximity for so many typhoid fever patients whose dejecta were carried into the river?

A. Only four in a day. The total number discharged from them that would go into the river would be relatively small, and the dilution would be very great.

Q. Are not the microbes in the human dejecta very great?

944 A. Yes.

Q. What are the facts in regard to that as a quantitative statement?

A. I gave you a statement in regard to the number discovered in urine, for instance. We find that one man, Mark Richardson, found 17,000,000 typhoid bacilli to the cubic centimeter in the urine of a typhoid fever patient. I suppose that would be a small number compared with the number found in the feces discharged from a typhoid fever patient.

Q. Now, suppose that four persons were afflicted at the same time, and the urine and dejecta were deposited in the Missouri River, within thirty miles of this city, would not that be a sufficient number to create and probably cause at least disease germs to appear in the St. Louis intake?

A. The number that would reach the consumer would be extremely small from these four people, from the daily discharge of four people in the Mississippi River, which we saw in a low river stage, discharges something like 24,000 cubic feet in a second, so the separation of the bacteria which would be discharged by four patients into that volume of water would be very wide apart, and it is possible that some of them might be carried into the intake tower and through it into the distribution system of the city to susceptible individuals, but the danger would not be very great.

Q. Take the City of Alton, twenty-five miles from St. Louis?

A. Yes, sir.

Q. Suppose there were, say, four people a day—forty-eight cases a year, of typhoid fever, twenty of whom died with the disease, all of whom deposited urine and dejecta into the Mississippi River, what would you say would be the danger to St. Louis, from the near proximity of cases of that kind?

A. We saw that the dejecta of each one of the inhabitants of Alton, when discharged and mixed with the waters of the Mississippi River passing that point, would be 1 to 70,000, and we—that we

traced very little evidence of the sewage of Alton at Hartford, seven miles below, bacterially, and consequently it would be again a very remote possibility of having bacteria coming from these pa-
945 tients into the intake.

Q. If you were afflicted with a typhoid epidemic in St. Louis, where as many as 200 persons were dying in a year during the recent years, and you could not trace the cause to any other source than one which you have imagined might be in existence in Alton, would not that sufficiently account for any trouble?

A. No, I think not, sir. Two hundred deaths would mean 3,000 cases of typhoid fever a least in the city, that is a great many sick at the same time out of a population of 1,675 to 700,000, with 90 per cent. of the bacteria removed by the reservoir to those who consumed the water. It would take a much larger infection than four people could produce even if above the intake. * * * It is a factor to be considered in this connection, in trying to trace the source of a typhoid epidemic everything must be brought to light. * * *

Q. Suppose there were as many as eighteen or twenty cases in a year in St. Charles. I mean that many deaths from typhoid fever in a year, and a corresponding number of patients who survived, all of whom deposited their discharges, both liquid and solid, into the Mississippi River, would not there be a danger from that source? * * * and all of whom deposited their urine and excreta into the Missouri River from the sewers of that town, would not that be a menace to the health of St. Louis?

A. Here, again, we have to take into consideration the question of dilution. We find there would be seventeen people sick a month with the disease, and that would not leave more than a certain number a day. It would be less than one a day discharging feces and if we have 360 days and 200 people, say, one a day were discharging feces into the river, with a death rate which you enumerated, that would be the dejecta of one typhoid patient into 79,000 cubic feet of water per second into the Missouri River, at low water stage, so there again you have the remote possibility of the bacteria from one case a day or two cases a day, reaching the intake of the St. Louis water supply. * * * To an equally susceptible individual the chances or a near-by bacillus having greater vitality are greater, so that the disease produced in an equally susceptible individual,
947 the disease produced by a near-by bacillus would be of more severe type than that produced by bacteria carried some distance.

EXCRETA.

Well, there are about three ounces of solid excrementitious matter and forty ounces of urine.

Q. That is per capita per day?

A. That is per capita per day.

Q. Well, now, is that from the statistics and experience of
768 people who have made experiments? Is that a fair average?

A. Yes, sir; that is a low average.

EXPERIMENTS.

Q. Now, are conditions favorable or unfavorable for the longevity of bacilli of any kind in a laboratory experiment, either in sterilized or non-sterilized waters, or the natural waters?

A. Well, from those results they would seem to be more favorable in the sterilized water and unfavorable in the stagnant living water in the bottle.

Q. Now, compared with the conditions in a running stream, or living waters, Illinois River, Missouri River, or the Mississippi River, where oxidation is taking place, and from all organic, animal and vegetable substances, would the conditions for longevity for typhoid bacilli be greater than it would be in any laboratory experiments, what would you say about that as a bacteriologist?

A. It is impossible to carry out in a laboratory experiment the conditions which obtain in a running stream, but the conditions in a living water, in a flask in a laboratory experiment, the bacteria are there in evidence; all the bacteria in that particular water, each of which produces a particular toxin or toxins, which is favorable to or delaterious to the life of the typhoid bacillus, also the contained infusorial life, so that in a flask in the living water in a very short time the toxins produced by the micro-organisms that are at work seem to act unfavorably upon the typhoid bacillus placed in that water. In sterilized water the typhoid lives, you see, quite a number of days. Now, what obtains in a running stream would seem to be this: That the typhoid bacillus would not be subjected to the poisons produced by other bacteria, so much as it would be in the stagnant water in a flask. In the running stream it certainly would not be confined to a given water because it can swim about, and also be carried along

by the running stream, so that its chances of prolonged life
478–479 would be, it seems to me, vastly greater.

Q. I will ask you if it has ever been possible, as far as you

know, to determine the absolute longevity of the typhoid bacillus in running water?

A. It is almost impossible to do it and it is not known.

Q. Why is that?

A. Because the conditions which obtain in a running stream cannot be produced in the laboratory experiments and to put living typhoid bacilli into living water, a water that was being used by human beings to drink, would be simply pure murder, so that the experiments cannot be made in a living stream.

Q. Now, do other bacteria in the water prey upon the typhoid bacteria?

A. They do not eat one another.

Q. Does the action of anerobic and the aerobic bacteria in disorganizing organic substances in the water destroy the life of the typhoid bacillus?

A. That seems to be the reason why they disappear in the stagnant waters in our laboratory experiments. We find that when we take water, for instance, from the drainage canal, that it contains on an average of 300,000 or 400,000 bacilli to the cubic centimeter. We show typhoid bacilli in this water, and for the first two, three or four days the water bacilli, not the typhoid bacilli, increase enormously and use up the nutritive material in the flask for food. The result of this destrictive action on the organic matter, both solid and liquid, in the water, results in the production of poison, true toxines and emzines in the water, and these products seem to act not only deleteriously upon one another, but upon all pathogenic micro-organisms in the water also, so that we see in the laboratory experi-
791 ments that the bacteria in the living water die much quicker than they do in sterilized distilled waters or than in river waters sterilized.

FILTRATION.

A body of engineers and expert filter men have been at work on that problem and they have made examinations without having carried out an adequate series of experiments on the water to
870 ascertain the facts connected with it, and nobody knows how to filter this water supply or what it will cost.

HEALTH REPORTS.

Q. Now, have you any record of the number of typhoid cases in this city at that time?

A. Yes, sir.

Q. How many were there?

A. Well, from the report of the chief sanitary officer of the health department for the fiscal year ending April 1, 1893, 3,624 cases of typhoid fever were reported to the health authorities by the physicians of the city, with a total of 514 deaths.

Q. That was April 1893?

A. April, 1893, his report was filed.

Q. For the year ending April?

A. He makes an annual report and the fiscal year ends March 31st. * * *

Q. Where did you get these figures, on the chart?

A. FROM THE ANNUAL REPORT OF THE HEALTH DEPARTMENT.

Q. Of this city?

411 A. Yes, sir; of this city.

Q. Does it show anything else besides these figures?

A. That is, from this period of January, 1890, to December, 1900, the map goes further, and shows another period which we will describe later.

Q. Now, from what data did you make that map?

A. This was made from data secured from the St. Louis Health Department and the official statistics of the Health Depart-

417 ment.

Q. What do the black lines mean?

A. They indicate the number of cases of typhoid fever reported to the Health Department. * * *

The better way to do that would be to have the report of the

419 Health Department and read the figures from that.

Q. Where did you get the data from which to make it?

A. The data of the typhoid cases was taken from the Health

433 Department.

I should say that these are the official statistics of the Health Department furnished me. I have it here. An executive session of the Board was held this day. Present, Mayor Wells, Dr. Starkloff, Dr. Merrill, Dr. Chapman, and Mr. Blong. Mayor Wells in the chair. The attached is a full, true and correct copy from the executive proceedings of the Board of Health in the manner and of the date above set forth. Signed by Mark Coffman, clerk of the

762 Health Commissioner and Board of Health.

INDOL.

Indol is one of the putrefactive products, the result of the
282 destructive decomposition or the destructive action of bacteria, upon organic matter.

POPULATION, RURAL AND URBAN, WITH RIVER DISCHARGES.

775 Table.

PRODIGIOSUS BACILLUS.

781-783 913-914 Experiment.

Prodigiosus lived from two to ten days and typhoid bacillus in sunlight and living water. Non-sterilized, lived from twenty-four hours to ten days.

928 Witness Kirschner will be recalled.*

RIVERS AND STAGES.

Q. Now, what result, if any, is shown there between the various stages of the river and the number of bacteria found in a centimeter?

A. Well, as a rule, running through the chart, when the river is falling it will be seen that the number of bacteria decreases markedly. When the river is rising the number of bacteria run
383 up to great heights.

Q. Now, from this map you have, I will get you to state if there is any relationship—if so, what—between the stages of the river as indicated by that map, and the increase or decrease of typhoid fever in the City of St. Louis in the years 1890 to 1900?

A. Why, I find in consulting this map that as a rule when the river is low that typhoid fevers were high, the number of cases and deaths.

775 Table of discharges of the Illinois River and its tributaries.

Q. Well, isn't it a fact that you know that the Illinois River only contributes about one-tenth of the volume of water that is contributed to the Mississippi River above Grafton and the Missouri at its mouth?

A. In these low river stages this would seem to be the case, because I find that just below Grafton in the Mississippi the minimum flow of 28,858 cubic feet per second was noted on January 11th, of

*No evidence in the record shows that these germs were ever deposited in the drainage canal.

the same year, so that would give the Illinois there 2,360 cubic
881 feet per second. That would be about one-tenth.
879 Comparative volumes of flow of the three rivers.

SETTLING BASINS.

It is interesting to note that the average number of bacteria in samples collected at this period during the second period of thirty-seven weeks was 56 per cent. of the number found in samples collected at intake tower. Forty-four per cent. of the bacteria in the water taken in the reservoir, therefore, were removed by these seventy hours' subsidence—by this sedimentation. We don't care to say anything about the third period at all. * * *

The colon bacilli was found in 65 per cent. of the daily samples collected in this point during this period.

Q. While it was in the state of sedimentation?

A. Yes, sir; after the seventy hours, we found 65 per cent. of coli in the daily samples collected at this point during this
196 period.

Q. Now, do you know anything about how long the water is allowed to remain in the settling basin after it is pumped from the intake tower?

440 A. Yes; from thirty-six to seventy hours.

Q. I believe you said that with the present system that you have that there is removed from the water from 90 to 98 per cent. of the bacteria?

A. In the reservoir system there is some seventy per cent. removed and to the consumer at a definite period of 1901 we found as high, I believe, as you speak of—90 per cent. to 95 per cent.
871 to the consumer of bacteria removed.

SEWAGE.

Q. Do you know how much sewage was carried into the Illinois River from Chicago in the year 1899?

A. I do not.

Q. Do you know whether or not there was practically the same kind of sewage carried into the waters of the Illinois River, the Chicago River, in 1899 as there is now?

A. I do not.

Q. You discharge all of your sewage into the Mississippi River here (St. Louis), do you?

A. Yes, sir.

Q. And have for many years?

A. Well, ever since the city was large enough to have sewers. I don't know the exact date. It seems to me it was in 1849 that the first sewers were built, but I am merely trusting to memory for that.

Q. What is the first town above St. Louis on the Missouri River?

A. St. Charles.

Q. How far is that?

A. I don't know; about 20 miles, I believe.

Q. Do you know whether it discharges its sewage into the Missouri River?

A. I have been told that it did by Dr. Morgan of that town.

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863 Q. Do you know that the sewage of Kansas City is discharged into the Missouri River?

A. Yes, sir; after resting in so-called cess pools for a time?

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869 Q. Is the sewage of St. Joseph, Missouri, carried into the Missouri River?

A. I have been told that it is. I don't know.

Q. Is the sewage of Leavenworth and the hospital of Leavenworth there carried into the Missouri River?

A. Yes, sir.

Q. Now, the Missouri River; what town on the Missouri that you know of, discharge their sewage into the Missouri River?

A. I know Kansas City. I don't know of St. Joseph by personal knowledge, but I know that they discharge their sewage into the Missouri. I mean I know that St. Joseph does. I know Kansas City does and I know that Leavenworth does. St. Charles does; also Jefferson City, I believe, does.

872 Towns on the Mississippi discharge sewage into the Mississippi.

Q. Now, then, isn't it a fact, from your understanding and knowledge, that the Mississippi River, the Missouri River and the Illinois River are used by the inhabitants of the various towns along these respective rivers for the purpose of depositing their

sewage in each of the rivers?

873 A. Yes, sir.

Q. During the time of low water, would not the effect of the Chicago sewage be more pronounced in the Illinois River than at flood time, when the drainage from all other parts of the drainage area came into the river?

A. IT HAS SHOWN LESS AFTER RUNNING A DEFINITE NUMBER OF MILES. THERE IS LESS TRACE OF IT IN THE ILLINOIS RIVER THAN THERE IS AT HIGHER PERIODS.

Q. You mean by that that the water showed less pollution during the period to which you refer?

A. I mean it showed fewer bacteria than were originally carried by the Drainage Canal after running to Peoria, than to Grafton, than it did in the season either following a freshet or when the river was high or steady.

892 Discharging sewage in that way is a reprehensible practice and drinking the water is a dangerous experiment.

956

TYPHOID BACILLI.

Q. Take the Mississippi River water here at St. Louis, what length of time do your experiments lead you to believe that the typhoid germ will live?

49 A. I think it is from as high as eight to 21 days.

The typhoid bacillus and the coli bacillus group do grow in the presence of carbolic acid.

468 Typhoid germs in sterilized water live 25 to 60 days.

469-470 Experiments on the longevity of the typhoid germ.

476 In the Illinois and Michigan Canal, at Lockport, unsterilized water 5 days.

Drainage Canal, Western Avenue, natural water in the window 6 days, and in the refgrigerator 7½ days. Drainage Canal, Lockport, natural water, window, 4¾ days, and refrigerator 10¾ days. Illinois River, above Peoria, average number of days alive in the window, 7⅞ days, refrigerator 11½ days. Chicago River, Adams Street, in the window, 4 days, in the refrigerator, 5½ days. Illinois River water, Pekin, natural water in window, 7 days, in refrigera-

477 tor, 15 days.

786 Typhoid lives in sterilized water 61 days.

789 Typhoid fever germs in dejecta of patients found by Petroski and Mark Richardson, 172 million bacilli to the cubic centimeter.

790 Typhoid bacilli found from 8 to 18 years after the disease.

791 Toxine of other bacteria injuriously affect pathogenic bacteria in laboratory experiment.

791 Typhoid germs can swim away from toxine.

Q. Well, what is your scientific knowledge on the question?

798 A. I haven't any, except what he, (Mr. Westbrook) has told me, except that this destruction of bacteria within a few hours in the sun-light or the destruction of typhoid bacteria in the sun-light in a few hours is a myth; it is not so.

807 It would seem that the condition which may obtain for the prolongation of the life of a typhoid bacillus in the running stream would be more favorable than the stagnant water of the laboratory experiment.

Q. Is there any reason for believing that typhoid bacilli exist for a long time in moist earth?

A. Yes, sir.

Q. What is it?

A. A number of experiments have shown that this is so. Experiments by Firth and Hornick, show that these micro-organisms live a long time in earth and sand that is moist, and retain their virulency.

Q. Do you remember the length of time?

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953 A. Twenty-five days in dry earth, and longer than that in moist earth.

TYPHOID FEVER.

832-833 Manner of contracting typhoid fever.

834 WIDAL TEST.

WATER.

837 Character of water in February, 1900.

Q. How many samples?

A. We took two samples September 6th and 9th. I collected those myself. Mississippi River, four miles above Grafton, September 6th, one sample. Mississippi River, six miles above Grafton, on September 6th, four samples. Now, then, there were two collected, Mississippi River, one mile above Grafton, September 21st; Mississippi River, four and one-half miles above Grafton, September 21st, one sample.

Q. Is that all?

A. That is all.

Q. How many samples did you take in 1899 on the Illinois River, above Grafton; that is, immediately above Grafton; or at the point where you took them?

A. Illinois River, just above Grafton, samples were taken September 9; Illinois River, one and one-half miles above Grafton, September 21st, one sample Illinois River; three miles above Grafton, Wheeler's Ferry, September 6th.

Q. Is that September 6th?

A. The first one was September 26th, Wheeler's Ferry, and September 21st, Illinois River, five miles above Grafton Bird's Home Club, September 6th, one sample. September 21st, one sample, Illinois River, seven miles above Grafton.

Q. Is that all?

846 A. That is all.

Q. Doctor, would you as a bacteriologist, be willing to give an opinion as to the pollution or known pollution of the waters of the intake for the years 1899 from the number of samples that you have testified about in the cross-examination?

A. You mean as to the cause of pollution, whether it was polluted or not; the water at the intake?

Q. Would you as a bacteriologist, be willing to give an opinion as to the pollution or known pollution out of the intake for the year 1899 from the number of samples that you have now testified about?

A. I could give an opinion upon the number of samples taken out of the intake at that particular time. I did.

Q. Would you as a bacteriologist, be willing to give an opinion as to the condition of the waters in the Illinois River above Grafton, in 1899 for that year?

A. For these particular samples at these particular times?

A. No, for the year 1899.

A. Knowing the stage of the river, I could.

Q. Your opinion is simply for the dates that you took the samples?

A. Just upon the date that I took the samples. * * *

Q. Would you, as a bacteriologist, state in your judgment as such, that that would be a fair test of the condition of the water in the Illinois River above Grafton for the year 1899?

847 A. I would not.

WATERSHED.

883 The watershed of the Missouri River embraces 530 square miles.

884 Watershed of the Illinois River, 27,914 square miles.

ILLINOIS AND MICHIGAN CANAL.

Q. You spoke about the sewage in the Chicago River, which was pumped into the Illinois and Michigan Canal having been in the condition of sewage preserved in a septic tank.

A. Yes, sir.

Q. In your opinion the pathogenic germs had been destroyed?

A. Yes, sir.

Q. Upon what do you base that opinion?

A. On experiments; personal experiments.

Page 961.

(Read following account of experiment.)

EDWARD H. KEISER.

Direct Examination 968
Qualifications 969

Q. Now, what two other branches of science are used in connection with the chemical analysis of water in determining its portability and the propriety and safety of using it for domestic and sanitary purposes?

A. Bacteriology. Bacterial science is used.

Q. Any other?

A. Analytical chemistry.

Q. What about microscopic examination?

A. I included that in bacteriology.

Q. Microscopic examination for the purpose of determining the potability of water,—has that any effect in the judgment of the chemist in determining the potability of the supply?

A. It certainly has.

Q. What effect has it?

A. In judging of the character of the water, the analyst is influenced by the number of bacteria found in the cubic centi-
971 meter of the water and also by the character of the bacteria.

Q. Is there any difference in the results of the chemical analyses of the same water when made at various temperatures?

A. Water changes very rapidly. The organic matter in water, especially that which we recognize as nitrites, is very apt to
973 undergo a change if the water is kept at ordinary temperatures or higher temperatures.

975 Determination of the Total Solids.

Q. And these different forms of chemical constituents found in the water are of chief importance in judging of the sanitary condition of the water?

A. The presence of nitrites and free ammonia, I regard as of chief importance.

Q. For what reason?

A. For the reason that the presence of measureable quantity of nitrites in drinking water is often regarded as a sure sign of contamination and a chemist finding a measurable quantity of nitrites in water, condemns that water as unsafe for drinking purposes, and so free ammonia likewise is of great importance in judging of
982 the sanitary condition of the water, for the reason that the first product produced by bacteria in decomposing sewage is free ammonia. We always find a quantity of free ammonia in sewage, so the chemist lays special stress on these two constitutents, namely, nitrites and free ammonia.

Q. Chemically, what is free ammonia?

A. Free ammonia is ammonium carbonate, or ammonium chloride, existing in the water that has been formed by the action
982 of bacteria upon nitrogenous organic matter.

When free ammonia and nitrites are found in water, it shows it is not able to take care of the contamination that is undergoing putrefaction and decay. The presence of these nitrites indicates there is decaying vegetable or animal matter in the water.

Q. That is the reason, then, that chemical substances are indications or warnings to the chemist that the water should be
983 looked upon with suspicion?

A. Yes.

Daily Averages of Nitrites in the Reservoir of the City of St. Louis from January to October, 1900. "We made daily analyses and from them made daily averages and from the daily
983-988-994-997-998-1004 averages we made weekly averages."

984 Table of Nitrites in St. Louis Waterworks from January 24th to October 11, 1900.

Q. Will you please give me the amount, average amount of

nitrites found in the reservoir of water from January 24, 1900, to January 31, 1900?

986 A. It was .0044 parts per million. That was before the canal opened; before it reached us here.

986 Maximum Nitrites for subsequent months of 1900.

February to April rise; May, June and July, decline in nitrites in the Mississippi River. "Our analyses point to the Drain-

989 age Canal as a source of them. The decline was due to high stages of the river."

Q. Now, is there any standard above which the amount of free ammonia should not rise in waters that are potable?

A. Yes, sir. When the amount of free ammonia in river water rises above .045 per million, the water is regarded with sus-

991 picion and it is generally recognized that such water is polluted. That will vary with the local history of the water and the local surroundings.

992 Table of Free Ammonia in Reservoir, January to October.

ALBUMINOID AMMONIA.

Q. What is it the product of?

A. It is the product of decomposing nitrogenous organic matter.

Q. Now, would that albuminoid ammonia be derived from both vegetable and animal matter in water?

1003 A. Yes, sir.

Taking all the results of the chemical analyses made by me from the period of January 24th to October 10, 1900, the conclusion is that the water became suddenly badly polluted about the first week in February as is shown.

Q. February; what year?

A. February, 1900. That is shown by a very large increase in the quantity of free ammonia and nitrites in the reservoir water, and this pollution continued during the months of February

1008 and March and began to diminish in April. This was co-incident with the increase in the volume of rivers.

Q. Now, regarding these three forms of ammonia as indices of water containing pollution, either of organic or animal matter, which is regarded as the higher form of pollution?

A. When we find free ammonia and nitrites present in considerable quantities, we regard the pollution as of animal origin and caused by sewage. Albuminoid ammonia, on the other hand, is not,

in itself, so characteristic of polluted waters, because albuminoid ammonia may be there of vegetable origin. * * * * * * * *

Q. It is a product of combining an outside agency with a substance in water?

A. Yes, sir.

Q. And produces albuminoid ammonia?

1011 A. Yes, sir.

Q. Now, considering all the facts heretofore set out with reference to your chemical work on the waters of the Mississippi River at points mentioned, the intake tower and points outside the intake tower on the Missouri and Illinois shores of the Mississippi River, on which side of the river is the water most polluted from a chemical standpoint?

A. On the Illinois side.

Q. Now, in regard to the sanitary character of the water, which side of the river at this point is the better water; on the Missouri shore or the Illinois shore?

A. The Missouri shore.

Q. Now, on the Illinois shore, the waters of what river were found, according to your chemical analyses?

A. The chemical analyses showed that the waters on the Illinois shore of the Mississippi River is Mississippi River water;

1031 on the Missouri shore is the Missouri river water.

Q. Now, the reservoir water of this city in the reservoirs up there at the chain of rocks, what are they, Missouri and Mississippi River water mixed; or are they the Missouri River water, or the Mississippi River water as disclosed by your chemical examinations?

A. The chemical analyses of reservoir water, showed that the water in the reservoir is a mixture of these two waters. This is shown by all of the data that we have, both for free ammonia

1031 and albuminoid ammonia and nitrates and nitrates and chlorine and solid matter. All the data show that the water in the reservoir is a mixture of Mississippi River water and Missouri River water.

Q. Now, from a sanitary standpoint, what is the better water: that in the reservoir of this city at the intake or that of the Illinois shore opposite the intake?

A. The reservoir water is better than the water from the Illinois shore opposite the intake?

Q. And from a sanitary standpoint, is the water in the reservoir better than the water from the Mississippi River on the Illinois River opposite the intake?

A. It is better than the water on the Illinois shore.

Q. Now, the water in the reservoir of this city, as compared with the water on the Missouri shore opposite the intake,—is it better or worse from a sanitary standpoint?

1032 A. It is worse.

1032-1033 Algebraic Formula for determining the comparative volumes of water.

Three-fourths of the reservoir water came from Missouri shore; one-fourth Mississippi River water.

Q. Now, how does the water of the Missouri River at Bellefontaine, compare with the water of the Mississippi River above the mouth of the Illinois as to being wholesome?

1034-1035 A. They are both fairly good streams from a sanitary standpoint, at those places.

1041 "Hartford is about nine miles above the intake and Alton is twenty-three; that is, fourteen miles above Hartford, by river."

The sewage of Alton apparently has no effect upon the condition of the river at Hartford.

Q. What is the reason of that?

1041 A. Its dilution is so small that it produces very little effect upon the character of the river as a whole.

Q. You say the nitrites are higher in the Illinois River above Grafton than they are in the Mississippi above Grafton?

A. Yes, sir; they are higher in the Illinois River above Grafton; very materially higher.

Q. Well, are the nitrites in the Mississippi River above the mouth of the Illinois higher than they are at Alton and at Hartford, and at the chain of rocks?

A. They are very much higher.

Q. Then is the Mississippi River, above Grafton, in a better or worse sanitary condition, than it is below Grafton, and at the chain of rocks?

A. Very much better.

Q. Well, from your examination, can you state chemically whether or not the Illinois River pollutes the Mississippi River?

A. The chemical analyses show that the pollution of the Mississippi comes from the Illinois River. * * * * * *

From a sanitary standpoint the water from the Mississippi River, above the mouth of the Illinois, is very similar to the water of the

Missouri River, and were it not for the inflow of the waters of
1042 the Illinois River, the Mississippi on both sides of the river at the chain of rocks would be of equal character; IT WOULD BE GOOD DRINKING WATER ON BOTH SIDES.

Q. Now, was the nitrites greater or less in the samples analyzed when you first began in January, 1900, at Peoria than it was at Grafton; in other words, was there more or less nitrites in the water analyzed in the samples taken January 24th from Peoria than there was in that taken from Grafton?

1045 A. At first we found less nitrites at Peoria than we did at Grafton in January. After the opening of the drainage canal they increased.

Q. Now, from these chemical facts, what conclusion do you draw?

A. I conclude from these analyses that before the opening of the drainage canal, there was sewage matter in the waters of
1045 the Illinois River, but there was greater oxidation in the region above Peoria, and immediately below Peoria; all along the river there was greater oxidation. That was shown by diminution.

Q. Can you state whether or not they have been increased or diminished by the opening of the canal?

A. Well, so far as my analyses go, there has been a decided increase since the opening of the canal in the amount of impurities that come down the Illinois River.

Q. Are these impurities sufficiently oxidized to be converted into harmless products by the time they meet the Mississippi River and the intake tower, situated therein in this city?

1048 A. In my opinion, they are not.

From my chemical examination it is my judgment that this pollution and the contamination from the Chicago River continues down through to the chain of rocks, and a portion of it finds its way into the intake tower or the waterworks and thence into the reservoir.

Q. Then I will get you to state whether or not, in your opinion, as a chemist, and from your analyses of these waters, the water supply of this city is contaminated by the Chicago Drainage Canal and the sewage emptied into it by the City of Chicago?

A. Yes, sir.

Q. What has been the effect of this in disposing of the sewage? Has it caused it to disappear, or does it cause it to be pushed further down the river?

A. It causes it to be pushed further down the Illinois River

and into the Mississippi River in greater quantities than before the opening of the canal.

Q. Now, of these two waters, the Missouri and the Mississippi, does your chemical analyses disclose which is the more potable and the better for domestic and primary uses, the Missouri River water or the Mississippi River waters?

A. The Missouri River water is far superior to the Mississippi River water opposite the intake.

Q. Does the Missouri River water contain any particular chemical constituents in a greater quantity than the Mississippi does?

A. Yes, sir.

Q. What is that chemical constituent?

A. It contains a larger proportion of common salt.

Q. IS IT THAT THAT EFFECTS THE FLAVOR OF THE MISSOURI RIVER WATER?

A. I think it does.

Q. Why is it that the Missouri River water is found to contain more of that salt than the Mississippi?

A. It has been found that one of the tributaries of the Mis-
1050 souri River that runs in from Kansas, flows over salt beds, and this gives it a larger proportion of common salt.

Q. Now please state again the amount of nitrites and free ammonia that is allowed in potable water.

A. In a surface water the averages generally accepted are, (that is, for free ammonia) the maximum amount is .05. When it goes above .05 parts per million the water is to be regarded with suspicion and if the albuminoid ammonia goes above .2 parts per million, then there is so much organic matter in the water that its contents are favorable for the growth and development of disease germs; then if there are measureable quantities of nitrites, if you can measure the nitrites, that is, express the results in numbers, we are usually
1052 inclined to condemn such water. If we can at all measure the amounts of nitrites, we condemn the water, as good drinking water has no nitrites in it, and whenever the chlorine goes above the normal amount, that is indicative sewage pollution.

1053 Monthly averages for chlorine for points on the Mississippi and Illinois Rivers.

1067 Odor noted in water.

1071 Odor of Missouri River.

The samples which I analyzed, and upon which I based my calculations, were taken above Peoria. I do not know at what point

with reference to Peoria, the samples taken from the Illinois River by Professor Long were taken.

Q. Give me the results of that, Professor.

A. The values before the opening of the Canal of free ammonia were 0.895, and after the opening of the Canal 3.060, according to Professor Long, and according to my analyses 1.950. The nitrites before the opening of the canal were 0.141, according to Professor Long after the opening, 0.060, according to Professor Long, according to my analyses 0.030. Albuminoid ammonia, before the opening of the canal was 0.572 by Professor Long, after the opening of the canal, 2.210 by Professor Long, and according to my analyses 0.627.

Q. Now, Professor Long's were made in 1900 from what dates?

A. From February to April, 1900.

Q. And in 1899, what were the dates?

A. From July to September, those are the averages.

Q. And those were made in 1900 at what dates?

A. In February and March, two months averages.

Q. What, chemically, does that show, with reference to the ammonias, nitrites, albuminoid ammonias, as to whether they have increased or diminished in the period covered?

A. It shows there was a very great increase.

Q. Now, that table shows that, from your figures alone, or the combined figures of yourself and Professor Long?

A. From the combined figures there is a marked increase here of the free ammonia, nitrites and albuminoid ammonia.

Q. Do Professor Long's figures show the same thing?

A. They do.

Q. What would that indicate; an increase of nitrites?

1076 A. That would indicate an increase of pollution of sewage.

CROSS-EXAMINATION.

Q. Before you commenced these analyses, had you traveled up the Mississippi?

A. No, sir.

Q. Or up the Illinois?

A. No, sir.

Q. Have you since traveled up the Mississippi with a view of examining the soil and the water, and the source of the water?

A. No, sir.

Q. Have you since traveled up the Illinois with such a view?

A. No, sir.

Q. Have you ever traveled up the Illinois with a view of determining the source of its water supply?

A. No, sir.

Q. Were you ever at Joliet or at Lockport?

A. No, sir.

Q. So that with the physical situation of the waters and the origin and derivation of the waters of which you have been testifying, you have no personal knowledge?

1080-81 A. I have not.

Q. Now, is there a standard of potability for surface waters of the Mississippi River?

A. Yes, sir; there is a standard of potability for river water.

Q. Now what is that standard of potability for river water?

A. Well, that standard is given in our text-books something like this: Free ammonia, not above .06 parts per million; then as to albuminoid ammonia, if it goes above .18 that shows that the nitrogenous organic matter in that water has approached the danger limit, if nitrites are in measurable quantities, that is, if we can estimate the number of nitrites and express it in figures. If we do get .001 per million or .002 per million, that condemns the water,

1096 because it has gone beyond the limit. Measurable quantities of nitrates condemn the water.

1097 In the Missouri River chlorine runs from 11 up to 23. If it was 50, we would suspect, then, sewage pollution.

ALGEBRAIC FORMULA ON CROSS-EXAMINATION.

1100-1101

If the fact was independent of algebra that the Illinois River at Grafton was less than one-tenth of the Mississippi in volume, it shows that as far as the nitrites were concerned, one-fifth of the nitrites were furnished by the Illinois River and four-fifths furnished by the other. They represent the amount of waters that are necessary to furnish that constituent to the Illinois. It means that that proportion of the whole, that much of the other water is required to furnish that much nitrites. It is not a natural determination of the volume of water.

Q. What you meant to attempt to do with that, and what you did do, as far as the mathematical formula is concerned, or algebraic formula, was to determine that if at a given point there are .0120 of free ammonia, and at some other point a certain other number of parts, and at a certain other point a certain other number of parts,

these two confluent sources furnished a certain ascertained amount of free ammonia at the given point?

A. Yes sir.

Q. So that it is theory and not actual water?

1102 A. Yes, sir; it is theory.

1103 One-sixteenth of the nitrites in the reservoir would come from the Illinois.

1104-1105 Weekly Averages of Chlorine at Bellefontaine, Missouri River.

1105-1106 Weekly Averages of Nitrites, Nitrates, Free Ammonia and Albuminoid Ammonia.

The albuminoid ammonia is largely of vegetable origin and the oxygen consumed does not furnish us very valuable information in this case, as it would in other waters where the contamination is more of a sewage character. The Missouri River is largely charged

1106 with vegetable organic matter in contradistinction to that which we find in the Illinois River, and therefore, the required oxygen does not furnish us any very valuable evidence, so I have not made the averages, although I have the daily determination.

Q. You said in explanation of the fact that the chlorines run high in the Missouri River; that there was some river in Kansas that was supposed to be impregnated with saline matter,—will you state what that river is?

A. I am not personally acquainted with the exact source, but I have been informed by the city chemist of the city of St. Louis, Dr. Teichmann, here, that one of the tributaries of the Missouri coming in at Kansas City, has come across salt beds in Kansas, and that is very highly charged with chlorine, and that is the reason for chlorine in the Missouri River.

Q. Do you not know anything about that, except what Dr.

1107 Teichmann told you?

A. No, sir.

Q. In making the analyses to which you have testified here, as to the condition of the waters at Grafton above the mouth of

1108 the Mississippi River, you did not take into account any supposed pollution that might have been brought to the Illinois River by the entering of its tributaries?

A. No, sir.

The tributaries would tend to pollute the Illinois River, such as the Kankakee, Fox, Big Vermillion. "The proportion of these impurities which came from the tributaries, would form a fraction of the impurities of the Illinois River, and the magnitude of that frac-

tion would depend upon the relative volumes of the Illinois and its tributaries, and it would vary as the volume of these tributaries vary."

Q. Then, in your conclusion as to the amount of pollution that is contributed to the Mississippi River at Grafton for the Illinois River, you take no account whatever of what might have come from the tributaries of the stream?

A. No, sir; I simply analyze the water as it is taken out of the mouth of the Illinois River.

Q. Then, so far as your analysis is concerned you charge up all the impurities which you found at Grafton to the Drainage Canal?

A. Well, in this way. As we ascended the river, and we found the impurities increasing steadily as we went up the river, I reasoned that if the impurities came slightly from the tributaries of the river, the quantities of free ammonia and albuminoid ammonia and nitrites would be pretty constant all the way up the river, and through the tributaries if the waters were homogeneous. They would show that on analysis, but we found as we ascended the Illinois River
1109 that there is a very great increase all the way up to Joliet where the analyses showed the water to be diluted sewage.*

Q. What was your standard in making these analyses as to the amount of chlorine?

A. Well, since my analyses disclose that the Mississippi River averaged in chlorine from four to five parts per million above Grafton, and since below Grafton the chlorine suddenly jumps to
1110 fifteen and sixteen parts per million, I conclude that that may be taken as evidence of contamination as regards chlorine.

Q. What is that?

A. That the Mississippi River, running four or five parts above Grafton, suddenly jumps up to ten or twelve parts below Grafton,—that is evidence of a contamination by the Illinois.

Q. What do you fix then as the safe standard?

A. Then the safe standard for the Mississippi should be four or five parts.

Q. What do you fix then for the Missouri River?

A. The Missouri River, however, runs from fifteen to sixteen parts normally, and we cannot use that standard very well for the Missouri. If the chlorine goes higher than fifteen or sixteen parts, then it indicates contamination, but owing to the fact that the Missouri is charged with salt from the salt beds, we are deprived from

*NOTE:—It will be observed that complainant's witnesses trace pollution from the mouth to the source, instead of from the source to the mouth.

using this standard in judging of the purity of the Missouri River.
* * * * * * * * *

Q. So it depends entirely on where the water comes from as to the potability of the water in reference to chlorine?

A. Yes, in order to use the chlorine standard, we have to have the so-called normal chlorine,—an average of what the chlorine would be in water in an uncontaminated state.

Q. Then, when you gave it as your opinion as to the potability of the water coming from the Missouri River at Bellefontaine, and the waters coming from the chain of rocks, the Illinois Shore,
1111 you had different standards in your mind. * * * *

A. As regarded the chlorine; yes.

1112 "Measurable quantities of nitrites indicate that the water is contaminated. If you have nitrites that you can measure, and readily represent in parts per million, it shows contamination of the water."

1112 Professor Mallet's Standard for Potability.

"When water comes above five-tenths parts per million of nitrites it is to be regarded with suspicion. The standard for free ammonia is that when it gets above .6 parts it is to be regard-
1113 ed as not drinkable or rather polluted,—that is .06 parts per million; that is, the average I should say for good waters, and when it gets higher than that we regard it with suspicion."

"I had no fixed amount in mind (for total solids), because our solids varied so very much in the Missouri River. In high water, it is so heavily charged with mud that the total solids cannot be used in judging of the purity of water."

Professor Keiser's comparison of Professor Long's analyses at Wesley City and the Peoria Narrows, wherein he confounds
1114–1132 Wesley City, which is below Peoria, with the Narrows above Peoria, for the purpose of comparison and his unwillingness to admit the mistake is found on pages 1114-1132.*

Q. Well, is it fair to compare the waters at Wesley—that is, below the sewage of Peoria, with the waters above Peoria, which is above the sewage of that city, for the purpose of making any sort of a calculation or deduction?

1120 A. I assume that that made only a very slight difference for the reason that the volume of sewage added by Peoria is

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*NOTE:—This cross-examination will show the witness' unwillingness to admit the unfairness of the comparison between Wesley City below Peoria and the Narrows.

comparatively small as compared with the bulk of sewage coming down the Drainage Canal.

1123 "Well, I wasn't aware that Peoria made very much difference in the water."

Q. Then you didn't know that Wesley was located below Peoria?

A. I didn't know where it was exactly, and I didn't know

1129 where the sewage of Peoria got into the river at Wesley. I thought it was considerably below, if anything. I didn't think it was right in the town of Peoria.

Q. Are we to understand from that that you regard the waters of the Missouri River as suitable for the water supply of the city?

A. Yes, sir. It is not as good as it might be, but still it can

1133 be used.

During the period of time for which these analyses were made, the nitrites run high, and the water (the Missouri River) was to be looked upon with suspicion; during the summer, nitrites are very low, and sometimes you can measure them with that amount I say that the river is a fair stream. It is not as good as we would like to have it, but still,—and during the winter months I admit that it is to be looked upon with suspicion according to the standards that I have given.

Q. Well, not suspicion only, but, according to the standards you gave, it should be rejected as polluted, should it not?

A. Yes, it ought to be rejected in its unfiltered state, according to these figures.

Q. Well, what would you say then of a source of water supply for a great city that four months of the year the water was unfit for use, and they were compelled to take it always from the same place?

A. Well, I should say it ought to be filtered.

Q. It ought to be boiled in addition?

1134 A. Boil anyway. You can filter it or boil and filter too.

RE-DIRECT EXAMINATION.

1138 It is not fair to make comparisons between the spring months and summer months from the same area of water in a running river.

1140 Comparison of the tributaries of the Illinois based upon Professor Long's report.

Report of the Illinois State Board of Health; advance notes
1141 of the sanitary investigation of the Illinois River, and its tributaries used by General Crow in re-direct examination of Professor Keiser, and not used on cross-examination.

Q. Do you know Professor, as to whether or not there are any large cities or towns whose sewage outfalls are into the—in any of the tributaries of the Illinois River below where the canal, the drainage canal joins the Desplaines River?

A. I do not. I know of no large towns that runs sewage into the tributaries of the Illinois.

Q. Now was that (meaning the algebraic formula) made for the purpose of determining the volume of water that flowed down the river from the Mississippi and the volume that flowed down from the Missouri as they comingled together in passing the intake?

A. It was made for the purpose of tracing these impurities that I have found in our reservoir water to their origin.

Q. Well, then, a chemical analysis of water does not constitute the measurement of the volume of the flow of water?

A. No, sir.

Q. Or body?

A. No, sir.

Q. Well, Doctor, the analyses as made by you determines the quantity of pollution as contributed by the two streams?

1143–1144 A. Yes, sir.

Q. Suppose where the Missouri and Mississippi come together the water of the Missouri was about one-third greater than that of the Mississippi, was polluted twice as great as the Missouri at the point of confluence, then would the amount of pollution found by water analyses below the junction of the stream correspond necessarily with the relative volumes of the two streams at the point of confluence?

A. No, sir.

Q. Why?

A. It would show, rather than the volume of the streams, it would show us the proportion of impurity which came from

1144 each of the streams.

Q. Now Professor, I will ask you, do you consider the water

1145 co-mingling with the Missouri and Mississippi as it comes into the intake of the St. Louis Waterworks since the opening of the canal, is a safe sanitary water for the use of cities of this size?

A. I do not.

RECROSS-EXAMINATION.

Q. Are there any waters in the navigable rivers of the United States that you would recommend people to use without being filtered and boiled for drinking purposes?

A. Well, I imagine there are some rivers. The upper Missouri is probably in a very good state, and it is navigable I believe for many thousand miles. I believe the Missouri above Kansas City and St. Joseph is a very fair stream, and that it could be used as a potable water.

Q. Below Sioux City, Iowa on the Missouri River and below St. Paul and Minneapolis on the Mississippi River, and below Pittsburg on the Ohio River, and below St. Louis on the Mississippi River, would you regard any of these waters as suitable for the best of purposes without some kind of treatment?

A. I think that all waters of our rivers ought to be filtered.

Q. Then there is danger of contamination from any of
1148 them, unless they are filtered?

A. Yes, sir.

1148 DR. WILLIAM C. TEICHMANN.

DIRECT EXAMINATION.

Q. Have you got any record of the samples you took up the Illinois River from August, 1899, to the 22nd of January, 1900?

A. Yes, sir; there were nineteen samples taken from the
1160 Illinois River at points 1, 2, 3 and 5 miles above Grafton.

"The Illinois River at that time was comparatively low. I say comparatively, because it has been lower at other times. I took samples at the mouth of the Missouri, probably a mile up stream, above the point of confluence of the two streams.

Q. How many samples did you take?

1161 A. Ten.

1163–1164 Volume Measurements of the Illinois River and its tributaries from Lyman E. Cooley's report read in evidence by Dr. Teichmann.

1166 Amount of sewage from Chicago according to Dr. Teichmann is equal to the water supply which is forty-two million cubic feet per day.

Quotation from Jordan by Teichmann as to the discharge from

the Illinois and Michigan Canal prior to the opening of the Drainage Canal was four hundred cubic feet per second.

1166 Q. Just go ahead and give your method of making these analyses.

1167 Q. Just go ahead and give your method of making these analyses.

Illinois State Board of Health Report quoted by Teichmann.

1174 "Now, it is true that dilution, sedimentation and oxidation gradually lessens the quantity of characteristic ingredients of sewage present, but not sufficiently by the time the Illinois reaches its mouth to have completed the process of self-purification, and the fact remains that all the tributaries entering the Illinois River are comparatively much purer than the Illinois itself. Now, that is a conclusion that I draw from these reports, that I have mentioned just now, that the tributaries of the Illinois River are all comparatively such. These are all conditions previous to the opening of the

1175 canal."

GENERAL HAMLIN: Now, have you a table there?

A. No; what I have had is the maximum and minimum. It is a very brief table and I have no copies. I can dictate it in a few minutes; it won't take long. From August 23rd to September 16th, 1899, four samples were collected near the intake of the water-works, but beginning with October 16th and ending January 22nd, 1900, semi-weekly analyses were made at the intake. The averages of the most important chemical constituents were as follows: Table averages, parts per million; nitrogen as free ammonia, maximum .138, minimum .008, average .0063 (?). That is the whole of that period at the intake. I will give the number of samples: 26 samples.

1180 Nitrogen as nitrites, maximum .01, minimum .0, average .002; nitrogen as nitrates, maximum .8, minimum .2, average .4.

When the Missouri River water would go into the intake the

1181 impurities of the water at the intake would be low.

Now, as to final conclusions on the work performed in the year 1899, I have the following to say: The Illinois River at its mouth was badly polluted during the entire period. The Mississippi River above the mouth of the Illinois was much better in sanitary quality than the Illinois throughout the investigation. The Mississippi River between Grafton and the St. Louis intake showed very much the effects of pollution from the Illinois River, and on such days when the Mississippi River water entered the intake the result would be an increased pollution of our water supply. The Missouri River was

enerally purer than the Illinois above Grafton, and purer than the Mississippi after its junction with the Illinois River.

1182 The second period of the investigation covers the time from January 23rd until October 11th, extending to December 1st, of the same year, in a measure. That is, for some point from which samples were taken. The examination was continued until

1182 November 30, 1900. I will state the points. From January

1182–1183 23rd until October 11th, 3,492 samples of water were collected and analyzed from the following points:

Teichmann quotes Jordan in his estimate of sewage discharged

1193 from Chicago.

1194 The ratio of dilution, based upon the population of say 800,000, would make a ratio of dilution from 1 to about 21.

From my own personal observation and from the reports of my collectors, I found out that in September the canal was prac-

1195 tically closed at Lockport, sometimes for days and nights, sometimes only for short periods.

Sewage in Drainage Canal Killing Fish.

1196 I might state various defects of the canal, and chiefly engineering defects, as showing the impossibility of permitting a flow of more than 250,000 feet per minute, cubic feet per minute,

1197 of the canal, but I can go over to the chemical examination and let that matter stand.

Except when the drainage canal is closed temporarily, then, the water flows back into the lake, as was the case in September, 1900, and these averages would probably be still lower, were it not

1198 for the fact that during September on certain days the Chicago River again flowed into the lake because of the temporary closing of the gates at Lockport.

1208 Q. MR. WOERNER: And your conclusion is?

A. That the Illinois River was very much more impure than the Mississippi River above the mouth of the Illinois during the year 1900, and was evidently in a badly polluted condition.

MR. WOERNER: Now, are you ready to state your conclusions in general, doctor, from these charts, or do you want to give any more data from which your conclusions are reached?

A. Well, my conclusions regarding the pollution of the Illi-

1211 nois River, you mean, or do you mean the final conclusions?

I have not reached that yet, because I have not spoken of the Mississippi River yet.

Now, regarding Peoria sewage, the population of the City of

Peoria, according to the census of 1900, is 56,100, and we calculate the sewage discharge on a ratio compared with the population; that is, we figure on 150 gallons of sewage there per inhabitant. On this basis we take 8,415,000 gallons, or 1,122,000 cubic feet of sewage for twenty-four hours, running in the Illinois River from the City of Peoria. That is, if we take the total population, but from recent data I have learned that the sewage draining from the City of Peoria into the Illinois River would represent only 47 per cent.
1212-1213 of the population.

Minimum flow of the Illinois River at Peoria, according to
1213 Lyman E. Cooley, 72,000 cubic feet per minute.

Ratio of dilution of Peoria sewage in the Illinois River of
1213 1 to 413 at low stages.

Q. Now, would that materially affect the pollution of the Illinois?

A. IN OTHER WORDS, IF WE TAKE THE SEWAGE OF THE CITY OF PEORIA AND RUN IT INTO WATER AT SUCH A RATIO OF DILUTION, THE SEWAGE WOULD, IN MY OPINION, AFTER A RUN OF FROM TWENTY-FIVE TO FIFTY MILES, BE SUFFICIENTLY PURIFIED WITH SO MUCH WATER ADDED TO THE SEWAGE, SO AS TO RE-
MOVE THE EFFECT—POLLUTING EFFECT OF THE
1213 SEWAGE ON THAT RIVER.

Q. Now, answer the question please. The question was whether or not in your opinion the sewage from the town of Peoria materially added to the pollution of the Illinois River?

Attorney General Hamlin: I object to that. It is assuming that the Illinois River is already polluted.

Mr. Woerner: Did you get the question, Doctor?

A. Yes, sir.

Q. Now answer it yes or no. The question is whether in your opinion the town of Peoria materially adds to the pollution of the Illinois River—

A. I would rather change that question, whether it has any effect.

Attorney General Hamlin: Never mind, Doctor; you are not the lawyer. You are the witness.

The Witness: Excuse me.

Mr. Woerner: Well, is the sewage from Peoria in your opinion such as to materially add to the pollution of the Illinois River?

A. It adds to the pollution of the Illinois River, but only to an extent that if the Illinois River were pure that would be what I

would call a comparatively pure water, because absolutely pure water is only distilled water which you find in the laboratory, but I mean to say, an ordinarily good river water, potable—I will say that if it were a potable water before it came to Peoria, that the sewage entering the Illinois River from the City of Peoria would, after running from twenty-five to fifty miles, purify itself, so as to remove the polluting effect of the Peoria sewage on the Illinois River.

1214 (NOTE—Read what follows.)

In other words, it is again demonstrated by the results as shown here for nitrites during 1900 that high nitrites at Grafton in the Illinois River were always followed by an increase at Alton and Hartford.

Q. What did that indicate?

A. That indicates that the Illinois River effectually pollutes
1217 the Mississippi River after joining it at Grafton.

Water coming down the Mississippi River along the Missouri shore as it passes St. Louis is principally consisting of Missouri
1218 River water.

1221 Conditions which give pure Missouri River water at the intake.

Another characteristic feature of this water is its high chlorine contents. These high chlorine contents are due to the drainage of the Kaw River in Kansas of salt deposits. In the investigation conducted in the year 1901 I had samples of water collected from the upper Missouri above and below Kansas City, and also from the Kaw River, which demonstrated chemically the very high chlorines in the Kaw River as drained from these salt beds. It may suffice to state that it is positively proven that high chlorines in the Missouri River between Kansas City and St. Louis are principally due to the
1224 drainage from these salt beds in the State of Kansas.

If the high albuminoid ammonias that are found in the Missouri River were due to sewage contamination, they would be accompanied by high nitrites and high chlorines. Now, I have demonstrated that the high chlorines in the Missouri River between Kansas City and St. Louis are not of sewage origin or of salt drainage origin in Kansas, because the Missouri River above Kansas City shows comparatively low chlorines. The nitrites in the Missouri River throughout the year are low. They are frequently absent. The Missouri River may at times show high ammonia, but never high nitrites, and the chlorines come in from the salt beds of Kansas by the Kansas River; we cannot ascribe the impurities that we find at the mouth of the Missouri River to sewage origin.

(Objection to all of the above by General Hamlin on the ground that no questions were being asked of the wit-
1225 ness.)

Tables of percentages of Missouri and Mississippi River water at the intake of the St. Louis waterworks, based on tables of-
1227-1233 fered in evidence on March 18, 1903.

Table of percentages of Missouri and Mississippi River water
1234 at the intake of the St. Louis waterworks.

The average percentage of removal of suspended matter in the reservoirs for the period of 1900, from January 23d until October 12th, represents 85 per cent., that is, 85 per cent. of the sediment of the water passing through the reservoirs remains in
1243 the reservoirs.

Our analytical results show that the water entering the intake in 1900 was more polluted than the water entering the intake in 1899, and that the increased pollution, since there was no corresponding increased pollution in the Mississippi River above the mouth of the Illinois, nor was there an increased pollution in the Missouri River above its mouth, it shows that the increased pollution of the water going into the intake tower must be ascribed to the increased pollution of the Illinois River in 1900, and since I have shown that the increased pollution of the Illinois River at Grafton was due to the increased pollution of the Desplaines River following the opening of the drainage canal, I feel justified in declaring that the opening of the drainage canal resulted in an increased pollution
1245 of our water supply.

1246 Third Period of Investigation.

1247 Fourth Period.

1248 Places where samples were taken for fourth period.

Two samples were taken from the Kaw River, which empties
1250 into the Missouri River at Kansas City.

1250 Different periods of investigation.

We find correspondingly low nitrites in the Desplaines River before the Illinois and Michigan Canal and the Chicago drainage canal strikes it. These nitrites are remarkably low. At times there are no nitrites in this river, and since there is such a small amount of free ammonia in that river and the chlorines are exceedingly low, we must call this the Desplaines River—before it is polluted by the sewage from the drainage canal and the sewage from the Illi-
1258 nois and Michigan Canal—a comparatively potable river water.

Drainage canal and Illinois and Michigan canal pollutes the
1259 Desplaines River.

Purification of the river from Joliet to Peoria a distance of
1263 124 miles.
Wave of polluted water increased pollution of Illinois River
1264 correspondingly during its entire course, etc.
Teichmann traces pollution from the mouth of the Illinois
1265 River to the drainage canal.
Comparative pollution of the Illinois and Mississippi Rivers for
1267 fourth period.
1268 Condition of the river in October and November, 1901.
And conclusions drawn from this period of these investigations
1268-1269-1270 are found on pages.

During one week the free ammonias were a little lower at Alton than they were in the Mississippi River above Grafton. They were also a little lower during the first week in October, but
1271 only to a very small extent.

If at this ime (1901) the nitrites of the Missouri River would be as high as those found in the Mississippi River at Hartford, or higher as was shown by the free ammonia, we could ascribe the higher free ammonia in the Missouri River to sewage pollution, but the nitrites are lower, and since the high chlorines in the Missouri River are not attributable to sewage pollution of the towns and cities on the upper Missouri, but are proven to be due to the drainage of the KAW RIVER, which runs into the Missouri River, at Kansas City, due to the drainage of the Kaw River through districts—vast areas of Kansas salt beds, it is to be concluded that the sanitary character of the Missouri River was better during this period than that of the Mississippi River after it was joined by the Illinois River and increasingly polluted by the Illinois River. If we take the figures for nitrites for this period we notice that the nitrites in the Missouri River at Fort Bellefontaine were low. They varied from .001 as a
1273 minimum to .065, the maximum.
Sample of water taken from Missouri River above Omaha, Nebraska, on November 13, 1901, showed nitrites .004, chlo-
1276 rine, 10 parts per million.
Second sample taken at Bellevue, Nebraska, on the Missouri River, on November 13th, was nitrites, .006; chlorine, 11.5.
1277 Sample taken above Omaha November 24th, nitrites, 001; chlorine, 11.
Sample collected ten miles below Omaha November 24th,
1278 nitrites, .0025; chlorine, 11.5.
Sample collected November 14th, at St. Joe, chlorine, 12.5;

November 14th, twelve miles below St. Joe, nitrites, .00[illegible];
1279 chlorine, 7.

November 26th, St. Joe, sample, nitrites, .006; chlorine, 16. Sample from Missouri River at Kansas City, one-half mile above the waterworks, nitrites, .005; chlorine, 24.2.

Sample from Missouri River, November 17, 1901, ten miles below Kansas City, nitrites, .005; chlorine, 18.

November 17, 1901, sample from the Kaw River at Argentine, Kansas, nitrites, .004; chlorine, 89.8.

November 28th, sample collected at Kansas City at the water-
1281 works, nitrites, .004; chlorine, 16.

November 28th, ten miles below Kansas City, nitrites, .004; chlorine, 23.

November 29th, Kaw River, at Argentine, Kansas, nitrites, none; chlorine, 109.

November 19, 1901, at Jefferson City, nitrites, .005; chlorine,
1283 20.

Herman, Missouri, 125 miles from the mouth of the Missouri River, chlorine, 9; three miles below Herman, November 20th, chlorine, 18.5. Herman, one mile above, chlorine, 19; below St.
1285 Charles, Missouri, chlorine, 19.

St. Charles, one and one-half miles below, December 23, chlo-
1286 rine, 23.

1289 Fifth Period of Investigation.

Q. Now, Professor, are you acquainted with the character of Lake Michigan water in front of the City of Chicago, in Lake Michigan, as to whether or not it is sanitary?

A. Yes, sir; I consider the Lake Michigan water as it enters
1293 the Chicago River polluted. It is not pure water.

Q. Now, from your examination of these streams, can you state whether or not the waters of the drainage canal pollute the Desplaines River?

A. It is my opinion that they do. The Illinois River is indi-
1293 rectly polluted by the drainage canal.

Q. Can you state from your examination of these waters that the water coming into the intake of the St. Louis waterworks now is less wholesome and less pure and less fit for sanitary use and domestic use than it was before the opening of the canal?

A. I think it is, yes, sir.

Description of the sewage of Kansas City and its sewers. Sixty per cent. of the sewage of Kansas goes into the sewers and
1296 drains into the Missouri River; 4,000 cesspools in Kansas City.

Q. Now, from your chemical examination as heretofore detailed by you of the waters of the Missouri River and of the Mississippi River at the confluence of the two streams, will you please state if you know the fact, which is the better for use for domestic purposes, and which is the more sanitary drinking water?

A. The Missouri River.

Q. Now, can you state from your examination of these waters which is the better water for drinking purposes, that in the Mississippi River above the mouth of the Illinois River or the waters of the Mississippi River below the mouth of the Illinois and prior to its junction with the Missouri?

A. The Mississippi River above the mouth of the Illinois.

The water since 1900 entering the intake has not been po-

1296 table.

1297 Stages of the Illinois River

1298 Illinois River in January, 1900.

1299 Mississippi River at Keokuk seven-tenths of a foot stage.

1300 Gauge readings continued.

Q. Do you know whether the drainage canal was closed during the greater part of September, 1900?

A. Well, it was closed during the daytime for several weeks, excepting Sundays.

"The volume of water running from the dam at night is estimated and represented at the table there. There was some water coming in, but in comparison to the regular flow it was a small flow. Do you want me to testify to that? This daily closing of the drainage canal at that time in September, 1900, resulted in the reversion of the flow of the Chicago River back into the lake and, as I have already testified, evidently resulted in an increase of the pollution of the water taken from the lake front, and as I also testified, I believe, but I am not sure about it, but think I did, that the Chicago River at that time in the reversion of the flow back to the lake again assumed this character which it had shown prior to the opening of the drainage canal. That is, its color was darkened again, and offensive odors and gas bubbles were noticeable along the route of the Chicago River during that period."

Mr. Todd: Did you see this yourself?

A. Yes, sir; I was in Chicago during that time.*

*Read what follows, 1306.

CROSS-EXAMINATION,

By Judge Johns.

Q. Doctor Teichmann, what is your idea or reason for calculating the volume of the Illinois River and its flow per minute of cubic feet, or per second of cubic feet, to place it at the extremest low water that you could find data for?

A. The low water stages are the most important in my opinion in calculating the effect of the sewage on the Illinois River because of the lower volume of water producing a lower ratio of dilution.

Q. Why not, if you wanted to strike a fair average of the ratio of dilution, select a mean stage of water?

A. Because a mean stage would be a theoretical condition, whereas a low stage would be calculating on the basis of an actual condition as it occurred. In other words, the low stage found at a certain time would be liable to return again, and then the conditions would be such as to produce a ratio of dilution much lower than the average would be, and we should then, as I have stated, have an actual condition to base the calculations on for future deter-
1380 mination.

Q. The idea was to calculate the smallest amount possible for dilution for the purpose of calculating the dilution of the river then?

A. Yes.

Q. Well, a low stage of water might continue for a day or a week or ten minutes, might it not?

1381 A. Yes.

Data secured from the report of Lyman E. Cooley, and the stages of the Illinois River secured from reports published by
1381 the Illinois State Board of Health up to 1899.

"I thought that the lowest stage on record would be exactly the stage to take, because it would possibly recur again, this lowest stage, and the lower the stage of the river, of course, the smaller would be the amount of water for dilution of the sewage in the
1382 river."

Stages and flow of the tributaries of the Illinois River, 110,034
1382 cubic feet per minute, or 18,339 cubic feet per second.

Q. Then where do you get your basis of 600 cubic feet of water upon which you calculate the basis of dilution and pollution?

A. Well, I got that from the figures as they were presented by Mr. Cooley in his report, and I thought I quoted them correctly; that is, figuring on a volume of water coming at the lowest stage on record there, from these rivers, and I have calculated that out on my

figures—the figures of Mr. Cooley agrees with the figures presented by Civil Engineer Harman for the Illinois State Board of Health in his reports. He finds that same volume, 600 cubic feet.*

Q. Then where do you get your figures of 400?

A. Well, you must take the total volume of sewage mixed with the water as it leaves the canal.

Q. That is precisely what I am doing, and assuming that 60 per cent. of the flow—36,000 feet—is Lake Michigan water, dilution, and 40 per cent. is sewage, as you say, then your statement of 400 feet per second for Chicago sewage is incorrect, is it not?

A. No, I don't think so, because the sewage, as it leaves the canal, is supposed to be the sewage as mixed with the lake water there. It is diluted sewage. You cannot base the calculation on the sewage there because it is mixed with the water and leaves the canal together with it. That is what is understood by the sewage leaving the Illinois and Michigan canal. It is, of course, the sewage mixed with the water there.

Q. Well, you say at the ratio of 40 per cent. to 60 per cent., Lake Michigan water, so that your assumption of 400 feet was incorrect by 140 feet, was it not?

A. No, sir; not the way I construed it and the way Mr. Cooley and Mr. Harman construe it in their reports. They calculated on the total volume leaving the canal and entering the Desplaines River, or rather at La Salle, and call it all sewage.

Q. Answer this question: If the flow from the Illinois and Michigan canal is 36,000 feet per minute, and if 40 per cent. of that is Chicago sewage, then, assuming that state of things, without any argument with reference to it, your assumption of 400 cubic

1384 feet per minute of Chicago sewage is a mistake, is it not?

A. No, I cannot admit that, because the mixture there is still sewage. It is a sewage mixture.

Q. I beg your pardon. You are now on the stand as an expert and I have a right to assume to you any question that I see fit to propound in the way of legitimate examination, and you are bound by the facts which I state. Being now bound by the facts which I stated, is your assumption of 400 cubic feet wrong?

A. No, sir.

Q. Assuming that the volume per second of Illinois River above Utica is over 18,000 feet and that the sewage of Chicago is 400 feet

*The assumption of 400 cubic feet of sewage for Chicago is not sustained by the figures, and his cross-examination fails to show how he secured such data, and the same is found on pages 1383-1384.

per second, your rate of dilution of 1 to 5 is also incorrect, is it not?

A. Well, based upon your premises.

Q. Now, then, assuming that the volume of the Illinois River above Utica before the opening of the drainage canal was in round numbers 18,000 feet, and that the sewage of Chicago was 400 cubic feet per second, what is the ratio of dilution?

A. The ratio of dilution would simply be their subtraction; 400 there and 18,000; that would be, of course, a very large ratio.

Q. Yes. Well, what is it?

A. 45.

Q. 1 to 45?

1385 A. Yes.

Q. Now, do you know that in this calculation that you have made here in the stage of the Illinois River above Utica you have left out a number of rivers—several?

A. Those rivers were left out because in the opinion of Mr. Cooley their stages were such that they were practically dry during that season of drought, so that Cooley omitted them from his calculation.

Q. Your entire argument upon the question of dilution of sewage is based upon an opinion of Mr. Cooley given in 1890?

A. Principally, yes; and also upon an opinion in figuring out these stages and averages in an opinion presented by Mr. Harman, the civil engineer for the United States Board of Health, pub-

1386 lished in 1901.

Q. What do you define sewage to be?

A. Well, sewage ordinarily is defined as the liquid contents of the sewers, but this definition would have to be modified some, because you cannot call it strictly liquid contents. It has solid matter in the contents of the sewers, so that you define it as the

1386 contents of the sewers.

Q. That is, in determining the amount of Chicago sewage, you say that if there is pumped for the use of the city into its mains 42,000,000 cubic feet of water per day, the sewage of the City of Chicago is 42,000,000 cubic feet?

1387 A. Yes, sir.*

1387 "I assume 42,000,000 cubic feet per day of sewage and that

*This statement does not take into account water used for any other purpose and it assumes the entire supply of the city goes into the sewage and is what the witness characterizes as a scientific argument, and the basis upon which investigators carry on their investigations.

includes the official consumption of all characters, such as has
1388 been converted into steam.

Q. Then the whole assumption excludes from use all water in the City of Chicago which doesn't return to the sewers again as water?

A. I cannot agree to that.

Q. Now, then, assuming that it is 42,000,000 cubic feet per day, how many cubic feet per minute is that?

A. Well, I would simply have to make a calculation that—291,666 cubic feet per minute.

Q. Now, where did you get your estimate of 400 cubic feet per minute for the sewage of Chicago?

A. Well, that was the Illinois and Michigan canal at that time. The total amount of sewage at Chicago was not pumped into the canal at that time; only a part of it.

Q. If the total amount was not pumped in, what would you say?

A. Well, that depends on the average that we take. I calcu-
1389 lated on 36,000 cubic feet per minute.

Q. If you know, what is the per cent. of chlorine alone in water which makes it unpotable, tell me.

A. I could not tell you that limit from that standpoint of its medical properties. It might be medical water. It might be good for certain diseases and contain very high chlorine, and then again ordinarily such water would have such a salty character that it would be unpotable.

Q. How much chlorine in water would make it unpotable to the average good healthy Missourian?

A. I think, of course, it is an approximation. It is very hard to tell, because a high amount of chlorine may be potable to a stomach of one individual and may not be potable to the other. It is very hard to try to limit that. There might be 1,000 parts of chlorine in that water, and yet people might be able to drink that water, and others again would reject it. It wouldn't agree with them.

Q. I have asked you a plain, simple question—what amount of chlorine in water would make it unpotable to a resident of Missouri? If you know, answer it, and if you don't, say so.

A. Well, I claim that there may be as much as 500 parts chlorine in that water and yet it may be potable.

Q. If there is any standard, state it, for chlorine in potable water.

A. No standard would be recognized that would condemn
1390 water solely on its contents of chlorine.

Q. At what seasons of the year, if albuminoid ammonia was to be attributed to the decomposition of fecal matter, would it be the highest in the Mississippi River?

1392 A. Well, it would be during the summer months.

Q. Did you ever make any chemical analysis of the waters of the Illinois River at Joliet before the opening of the drainage canal?

A. No, sir.

Q. Did you ever have anybody do that?

1394 A. No, sir.

Q. Did you ever make any analyses of the water of the Desplaines River at any point before the opening of the drainage canal?

A. No, sir. I have no personal knowledge in any way of the condition chemically, either above or below the place where the drainage canal flows into it, of my own personal analyses of
1395 the water.

Below where the Illinois and Michigan canal discharges the Illinois River, if there is a stretch of river, say three miles, in which the current was very slow, scarcely perceptible, that would op-
1396 erate as a septic tank.

Q. If there is another stretch of twenty-three miles, that would also operate as a septic tank?

A. Yes, sir. A series of septic tanks would have been beneficial in a measure.

Q. Do you know anything about the grades and descents of the Illinois River?

A. Oh, I have a slight knowledge of the same, a study of reports written by responsible authorities.

The lakes and bayous and estuaries of the Illinois River would
1397 operate as septic tanks.

Q. In making the cross-section of the Illinois River, how many samples did you take?

A. Well, the cross-sections taken at Pekin and Peoria represent three sections across the river. That is, we took the center of the river and then the right and left shore coming down the river.

Q. Only taking three samples for a cross-section?

A. Yes, sir; right there.

Q. Now, have you presented anywhere the results of the analyses of the cross-sections?

A. No, sir; they have not been presented as yet.

Q. There is no chart or table of these cross-sections in your testimony?

A. Well, thus far they have not been testified to.

Q. I asked you if you had stated anywhere the results of the analyses of the samples taken in these cross-sections.

1398 A. No, sir.

Q. You say that the drainage canal was closed practically during that month?

A. It was closed a number of days during the month of September.

Q. Entirely closed?

A. During the daytime, yes, sir. There were repairs at the dams there and the regulations in the river, without improvements made in the Desplaines River, that necessitated, as I was told,

1401 the closing of the bear-trap dam.

Q. From what source did you get the information that only 47 per cent. of the population of Peoria discharged its sewage into the Illinois River? A. Well, now, that I found in a report published by Mr. Harman, civil engineer, in the Illinois State Board of Health Report for 1900.

Q. You don't know that by any personal examination whatever?

1402-1403 A. No, sir.

Q. But in proportion to its population, 56,000, say, the amount of solid matter dumped into the river, not coming in through the sewers at all, is very largely out of proportion, very largely in excess of the population?

A. Well, if we draw approximate comparison, with a great

1403 many cities, any other cities that have similar manufacturing industries, I don't consider it very much out of proportion.

Q. Do you know that the solid matter and sewage of the city of Peoria is very largely in excess of that supposition you made?

A. I don't think it is largely in excess.

1404 Q. Will you say that it is not?

A. I don't think it is. It is not. That is my opinion.

Q. If the sewage of Peoria will purify itself of the dilution which it received from the Illinois River in a run of from 25 to 50 miles down the river, why will not the sewage of Chicago discharged at Lockport purify itself in a run from Lockport to Peoria?

A. First of all, the sewage of Peoria cannot purify itself by such a run of from 25 to 50 miles under the condition prevailing in

the Illinois River; that is, the water of the Illinois River as it reaches Peoria not being sufficiently pure.

Q. That is to say that the water of the Illinois River, when it receives the pollution of Peoria, is not in such a condition as to add materially in reducing and purifying the Peoria sewage in addition to the burden which it already carries?

A. The water in the Illinois River as it reaches Peoria and passes down is confined to the current in the Illinois River. The sewage from Peoria is discharged into the river near the shore. The character of the shore is such, from my personal observation, that the sewage, as it enters the Illinois River from the sewers, does not reach the channel right away. The river makes certain curves between Peoria and Pekin; there is a considerable slackening of the speed of the river along the shore, and this sewage from Peoria has a considerable time to perform certain initial purification processes along its route, where in the channel the current is faster, and this sewage from Peoria, when it reaches the channel, has finally remained for some time along the shore, and has undergone certain processes of initial purification. The chemical analyses of the cross section showed that. It has been in the septic tank adjoining
1405-1406 the current in the channel of the Illinois River; in a measure we can call that a septic tank.

Q. If the waters of the Illinois River were of the same volume that they are now, that the drainage canal is opened, and were potable when they reached Peoria, and then received the sewage of Peoria, would they purify themselves in running from 25 to 50 miles?

A. If that water, the Illinois River water, as it reached Peoria, would be pure from the analytical data obtained from the examination of the samples of water obtained between Peoria and Grafton, the conditions described by me prevailing in the Illinois River, between Peoria and Kingston, and through the lower towns there, this analytical data would demonstrate that chemically, the effect of the pollution of the Illinois River would not be noticeable. I have previously stated it would take from 25 to 50 miles for that sewage to
1407 disappear in the channel of the river not to be noticeable in the channel of the river, the effect of it.

(Read what follows.)

Q. Now, take your chart No. 9; where did you get your data as to typhoid fever?

A. The data as to typhoid fever were obtained from the Health Department—the Health Commissioner's office of St. Louis.

Q. Out of what kind of a book or paper?

A. These data were obtained by one of my assistants and received by him from an official in the Health Commissioner's office who tabulates that..

1431 Q. Do you know whether they were taken from reports, printed reports, or from records written?

A. My instructions were to take them from the official re-

1432 ports.

Q. Can you explain why the typhoid fever in St. Louis did not visibly increase from the 20th of March to the 14th of August, 1900?

A. I will have to go back to the river stages of the Illinois and Mississippi rivers above the mouth of the Illinois to answer that question. During the month of February, 1900, after the opening of the Drainage Canal on January 17th, the Mississippi River above the mouth of the Illinois River was low. At that time, evidently, the volume of Mississippi water which met the Illinois River was low, so that there was much more Illinois River water in that mixture coming down in February than there was after the rise of the upper Mississippi River above the mouth of the Illinois River in March, which I also showed. I showed a very marked rise of the Mississippi River water above the mouth of the Illinois River, so that the Mississippi River water coming down in March there, the Mississippi River water evidently had a much larger portion of Mississippi River water than Illinois River water, and the Illinois River water being represented in a very small percentage of that time because of the larger volume of upper Mississippi River water coming down. That water was entirely different in its chemical character from the water coming down in February. In February the upper Mississippi River above the mouth of the Illinois was low. The water then represented in the mixture at the Intake—I want to say that evidently there was a larger percentage of Illinois River water—of that mixture—going into the Intake in February and being represented by a high percentage, one day as high as one hundred per cent., going down again, and then going up again, in February, up to ninety per cent. There was more Illinois River water in that mixture. That was followed by a rise in typhoid for the month of March.

Q. Now, why did the typhoid fall and the percentage of cases

1433 fall when the Mississippi River was at 100 per cent. on the 27th, or in the middle of April?

A. Because, then, at that time, the Mississippi River water had a different character than the Mississippi River water coming down

in February, and it had a larger percentage of Upper Mississippi River water and a smaller percentage of Illinois River water.

Q. So that the chart does not contain anything about the Illinois River, but simply assumes that when typhoid fever is bad the Illinois River water prevails?

A. From the stages of the river, as officially recorded by the Weather Bureau, it is evident that the first big rise in February was due to the Mississippi River at that time; a rise in typhoid followed; a period when there was very much more Illinois River water in that mixture than there was subsequently, when the second great rise or percentage of Mississippi River water came.

The second great rise represented largely upper Mississippi River water above the mouth of the Illinois River, and the proportion being much larger than that of the Illinois River at that time, the Illinois River water was, of necessity, represented by a smaller
1434 percentage. This was not followed by typhoid in St. Louis, and that is what the map is to indicate.

Q. Do you know the cause of any one or more cases of typhoid fever in St. Louis after 1900?

A. Well, I have not treated any cases, because I am not a physician.

Q. You either know or you do not. Which is it?

A. Well, I am familiar with the history of quite a number of cases.

Q. For example, give me the history of one case.

A. Well, I cannot recall any particular one just now.

Q. Well, give me the history of three.

A. I cannot recollect, because these cases, as I studied them, were simply from information that I have received from coming in direct contact with physicians who treated the cases of typhoid fever, and from the study of reports and the study of books that were written on that subject.

"I have instituted an investigation to ascertain from the official data of reported cases of typhoid fever and a personal inspection of every case during one year by inspectors who were instructed by me to examine the cases. I have ascertained that a large majority of cases of typhoid fever in St. Louis reported during one year after the opening of the Canal—that these cases all correspond with the fact that the patient had been drinking city water during that
1435 period."

"I do not know what proportion of the people of St. Louis use the water from the city water supply."

Q. How many cess-pools are there in the City of St. Louis?

A. Well, I do not believe there is a record establishing just how many there are.

Q. How many wells are there in the City of St. Louis?

A. The number of wells in the City of St. Louis about four years ago, when I gave particular attention to that question, probably amounted to from 3,500 to 4,000.

Q. Not more than that?

A. No, sir. There are quite a number of cisterns in addition to that; so that we usually say there are 7,000 cisterns and wells in the City of St. Louis.

Q. What proportion of those typhoid fever cases were suffered by people who took water from wells or cisterns?

A. It was ascertained in this special investigation, that of the 1,160 or 1,180 cases reported in 1900, of typhoid fever, three-fourths of the patients did not drink any well water or cistern water; but only drank from the city supply. The others admitted that they drank well water, but frequently would also drink water from the water supply besides.

Cross-Examination by Mr. Todd.

Q. During the time that you have been connected with the Board of Health of St. Louis, has there ever been a letter sent out to the physicians in the city asking them to report typhoid cases coming under their immediate care?

A. Yes, sir.

Q. When?

A. There was one issued in the Fall of 1900, and another one issued in the Fall of 1901.

Q. Previous to the one issued in the Fall of 1900, do you know of any letter being sent out to the physicians in St. Louis during your term in connection with the Health Department of the City of St. Louis?

A. There was not exactly a letter sent out; but I remember as long as I have been connected with the Health Department that the Health Commissioner has frequently requested physicians, through the press and in official reports, to report the number of cases of typhoid more promptly.

1439 Q. But in 1900 there was a special letter sent to all physicians, wasn't there?

A. Yes, there was a circular letter issued by the Health Commissioner, calling the attention of physicians to the fact that the law

required them to report all cases of typhoid and all deaths from typhoid promptly.

Q. Were there responses to that letter generally?

A. Well, this way; the attention of physicians was called to the requirement of reporting cases. Now, whether they reported them more regularly after that I could not tell.

Q. You got a great many replies to that letter, did you not?

A. No, there were no replies necessary.

Q. I mean reports?

A. Well, it happened to be that these circular letters were issued just at a time that typhoid had gone up in St. Louis. The number of deaths had increased and the number of cases had increased; and, naturally, at that time, whether or not there had been a circular issued at that time, I presume that the number of cases reported would have increased.

Q. Well, that letter stimulated the doctors in reporting cases of typhoid, didn't it?

A. Well, it called their attention to the violation of the law in not reporting those cases.

Q. Was there any violation penalty attached to the violation of that law?

A. I don't know what the penalty is; but I know that physicians can be compelled to report those cases.

Q. Do you know whether there is a penalty attached to the law compelling physicians to report typhoid cases, or other epidemics?

A. I cannot tell you just at this moment.

Q. Well, assuming that there is a penalty attached for the violation of that law, do you know that there is any case previous to 1900 where the law has been invoked against any physician for not reporting a case of typhoid in the City of St. Louis?

A. I do not know.

Q. At the time that letter was sent out the question of opening the Drainage Canal was being agitated in the public press of

1440 St. Louis, wasn't it?

A. Yes, sir.

Q. And the Health Department of St. Louis?

A. Yes, there was considerable discussion. An investigation was going on at that time of the analysis of the samples, etc., and that attracted considerable attention.

Q. For seven years previous to the sending out of that letter, do you know of any publicity such as was given in 1900, as having

been to the health condition of the City of St. Louis by the public press or by the Board of Health?

A. Yes, sir.

Q. For the securing of data on typhoid?

A. Yes, I remember that when the typhoid epidemic of 1892 or 1893 came it was discussed very much.

Q. That was eight years previous?

A. Yes, sir.

Q. I mean seven years previous?

A. Yes, there was some discussion. There always is in connection with the discussion of the water supply and the warning issued by the Health Department against the use of the city water and the necessity of boiling, etc.

Q. Now, your physicians pay more attention to the enforcement of that law than they did prior to 1901?

A. Well, that I could not tell. It is my impression, though, that they pay considerable attention to the typhoid situation
1441 in St. Louis.

Q. Were there 500 cases of typhoid in the City of St. Louis in 1889?

A. There were more cases in 1889 than 500; that is, during the entire year. Typhoid was very low, but during one month they went up some.

Q. To what was that increase attributable?

A. That increase in typhoid was in 1899.

Q. The Drainage Canal had not been opened then?

A. That I could not tell.

Q. Did not you give that any consideration?

A. I gave it some thought, and I have some views on that subject.

Q. Could you favor us with your views?

A. I have not got anything. I have not come to a definite conclusion as to the result of the investigation that I had carried
1443 on at that time, and I am not prepared to make a statement.

Q. Assuming that the statements made by Dr. Ravold correctly state the number of typhoid cases in 1899 and 1898, in your investigations have you tried to ascertain what the causes were for that typhoid?

A. Well, I have attempted to investigate the matter; but I finally concluded that I might as well leave it to the chief of
1443 the bacteriological investigation, Dr. Ravold, who took up the matter and carried it on.

Teichmann attempts to give an explanation for the increase of typhoid fever in St. Louis in 1900, and his explanation appears on pages 1444-1445.

Q. During the five years previous to 1900, was the water supply of St. Louis, as found in these hydrants, good potable water?

A. No, sir.

Q. Did it require boiling?

A. Yes, sir.

Q. Did it require filtration?

A. Yes, sir; it should have been filtered.

Q. Now, do you compare potable water or drinking water as being bad or worse?

A. I do compare the analytical results in 1899 prior to the opening of the canal—I compare those results with those of 1900, 1901 and 1902, after the opening of the canal, and the water
1446 has become worse in its chemical character since the opening of the Drainage Canal.

Q. But before that it was not drinkable, was it?

A. Frequent warnings were issued by the Health Department and myself to boil the water or filter it well before drinking it.

Q. Why were those instructions given, doctor?

A. Because the water was not found to be potable.

Q. Would the water, as it exists to-day, if filtered or boiled, be as good as the water that existed prior to 1900, if boiled or filtered?

A. Presumably it would.

Q. For how long a period of time has the Health Department of St. Louis advised the citizens not to drink the water of St. Louis?

A. Oh, that has been done since 1893; since I assumed charge of the office of City Chemist and analyzed the water.

Q. What was the character of the pollution of the water in St. Louis prior to the opening of the Drainage Canal?

A. The water as proved to be prior to the opening of the Drainage Canal was polluted.

Q. With what?

A. The analytical results showed pollution in a measure from sewage and in a measure of vegetable origin.

Q. At that time was the Missouri River water potable
1447 water?

A. Yes, sir.

Q. And is the Missouri River water now potable water?

A. Yes, sir.

Q. Doctor, you have given no attention to the study of bacteriology?

A. I have some, yes.

Q. You don't class as an expert on bacteriology, do you?

A. Well, bacteriology, as connected with the chemistry of water, I have given some—considerable study.

Q. Then, in your testimony, you testified in this case as a bacteriological-chemical expert?

A. I testified as a chemical expert who is supposed to make himself familiar with all the bacteriological features connected with the chemistry of water.

Q. Now, with that understanding, did you regard the waters of the Missouri River as being potable waters, chemically and bacteriologically, prior to the opening of the Drainage Canal?

A. Well, chemically I am prepared to answer that question "yes"; but bacteriologically I am not prepared to answer the question.

Q. Why, doctor?

A. Because I have not given the strictly bacteriological feature of that water any special study; that is, I studied the bacteriology of the water as far as it is connected with certain chemical changes going on in the water. For instance, the action of an-aerobic and the aerobic bacteria. It is my duty to inform myself on that point; but I have not made investigations strictly on the bacteriology of the water, such as determining and making the counts and
1448 the determination of the presence of pathogenic bacteria, etc.

Q. During the year, what proportion of the year did the citizens of St. Louis drink Mississippi water prior to 1900?

A. Well, that cannot be estimated according to a particular time or season of the year. The amounts of Missouri and Mississippi River water coming down the channel and prevailing in the channel and then going into the intake all these years varies considerably—varies daily; and it is very difficult to generalize there, but, approximately, taking the whole year together, I am prepared to say that about 75 per cent.; that is, the daily quantity of water going into the intake would be Missouri River water—and about 25 per
1449 cent. would be Mississippi River water.

Q. That is during the year?

A. Yes, during the entire year; but it may vary so much that on one day it would be a very high percentage of one river and the next day turn right around and show probably a difference of fifty per cent., just according to the stage of the river and the

volume of water coming down from the watersheds of the
1450 big rivers—the three big watersheds—the Illinois, Missouri and the Mississippi.

Q. The results at the City Chemist's office would answer my question, and that is, is the water polluted the year around?

A. Yes, sir.

Q. By the Mississippi River water?

A. It is considerably polluted always when the percentage of Mississippi River water, as estimated from the residue on evaporation of those two rivers, etc.

Q. Was the water supply of St. Louis potable all the time or was it polluted? I am talking now of previous to 1900.

A. As I have stated in my testimony, on direct examination, the water supply of St. Louis, as coming from the water going into the Intake, was potable at times. I said in my conclusions there were great variations, and at some times the water would be a good drinkable water. The water would be potable. And at other times it would be very bad—polluted, as I said.

Q. What I want to get at is, what is the proportion of time that it was polluted to the time it was potable?

A. That I could not estimate for that period, because I did not make daily examinations at that time. I did not take
1451 daily samples during 1899, prior to the opening of the Canal.

Q. Now, above Grafton, was the water of the Mississippi River, prior to 1900, potable?

A. The water of the Mississippi above Grafton—yes, it was.

1452 Q. From the analyses, what conclusion did you draw as to the potability of the waters of the Desplaines River?

A. I stated in my testimony that I considered that water
1457 potable.

Q. And you say that that water was potable?

A. Yes, sir.

1458. Q. You mean by that, good drinking water?

A. Yes, sir.

Yes, my analyses established the fact that during those two months the water taken from the DesPlaines River was potable
1459 before it reached the Drainage Canal.

Q. What is your opinion as to whether the sewage of a population of 500,000 inhabitants being emptied into a river the size of the Mississippi at St. Paul and Minneapolis, at what distance would the waters of the Mississippi purify themselves and become potable after receiving the sewage of St. Paul and Minneapolis?

A. I have not made any analyses of the waters between St. Paul and the mouth of the Illinois River, excepting a few miles on the Mississippi above the mouth of the Illinois, so that I am not prepared to make a statement answering that question.

Q. Have you any opinion as to whether the Mississippi River,
1461 after receiving the sewage of St. Paul and Minneapolis, subsequently purifies itself?

A. No, sir.*

Q. Then, if the waters of the Mississippi River for four months during the summer are potable, is not the conclusion irresistible that a running stream the size of the Mississippi River will purify itself from impurities and from all sewage that has been discharged into it above Grafton?

A. Such a conclusion would not be justifiable unless based on a careful study of all local conditions; the character of the pollution of that water; the amount of sewage being discharged from all of these cities into the river; what the distances are, etc., of the towns to the point at the mouth; the volume of water; the weather conditions; everything would go into consideration. No hard and fast rule could be evolved from such a theoretical question.

Q. Doctor, if the waters at Grafton were chemically decided to be potable, is not the conclusion irresistible that the sewage, however magnified, or increased, in the upper Mississippi has been purified by the time it got to Grafton?

A. It would demonstrate that the pollution of the Mississippi River above Grafton is of such a character that it does not affect the potability of the water of the Mississippi at the mouth of the Illinois.

Q. And how is that question of potability arrived at, aside from the theory that running water purifies itself in a certain distance, if the analyses of the water demonstrates beyond question that the waters at Grafton are potable?

1468 A. It is possible that such purification may take place, but it is necessary for various conditions all to co-operate to being favorable to such a result being obtained.

Q. Do not all conditions operate favorably, and do not the

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*Witness asserts that the water of the Mississippi River above Grafton was potable, but refused to express any opinion as to whether the Mississippi River, after receiving the sewage of St. Paul, Minneapolis, McGregor, Prairie du Chien, Dubuque, Keokuk, Davenport, Rock Island and all the cities lying tributary to the Mississippi River, and emptying their sewage into the Mississippi River, purifies itself of said sewage, as he had not made an investigation covering the Mississippi River, but he found the water pure and potable at Grafton. 1461 - 1462 - 1463 - 1464-1465-1466 et s-q.

waters' sewage contaminated become purified when such results at Grafton obtain?*

Q. The water can only become potable by being purified; is that correct?

A. It may be potable without having been impure.

Q. Well, assume that it is in the chemical condition at the time that you denominate it as potable, and previous to that point it was sewage contaminated, does not the conclusion of potability carry with it the idea of purification for water of the character of that
1473 described?

A. No; water may be potable and yet may not be pure.*

*Purification is expressed as laboratory water in the answer of the witness.

Q. Now, if the water of the Mississippi River at Grafton is potable, does it not convey to your mind, as a chemist, that sewage discharged into that river at Minneapolis and St. Paul and all the cities nursing the banks of the Mississippi River, has become purified to the degree of potability by the time it gets to Grafton, the point where you made your examination?

A. Stating, as I have done, that I am not familiar with the conditions, whatever pollution there might have taken place in that Mississippi River above the mouth of the Illinois River, whatever pollution has taken place, it has been rendered sufficiently harmless by the time that water reaches the mouth of the Illinois River; whatever pollution has taken place, it has been rendered sufficiently harmless by the time that water reaches the mouth of the Illinois as to render that water potable during certain times of the year, as I have stated.

Q. That is the question that I was after.

A. Yes, sir.

Q. During the other eight months of the year, doctor, are the waters of the Mississippi River potable?

A. They are, more or less. That may depend upon certain conditions as found by the chemical analysis.

Q. Well, are they more or are they less?

A. I do not think that the impurities found during the other months of the year in the water taken from the Mississippi River a few miles above the mouth of the Illinois; I say, I do not think that the impurities found at that time would very much affect the potability. There might be a slight increase in the impurities, and yet our analyses demonstrate that from a liberal standpoint that water

*Following, appears the reasons why he cannot state that the Mississippi River purifies itself of all sewage which empties into the river by the time it reaches Grafton. 1469-1470-1471.

coming from the Mississippi River and subsequently mixing with the Illinois River, that is, on the whole, potable water.

Q. I am speaking above Grafton?

A. Above Grafton—that is what I mean. I say that some parties might say that the water in the Mississippi River above Grafton is not potable.

Q. I want to know what you think.

A. My opinion is that it is, practically throughout the year; it is permissible as good drinking water.

Q. Doctor, assume that Grafton was a large city and you were placed in charge of the water supply of that city as a scientific man, would you advise the citizens of Grafton to use the waters of the Mississippi River above the entrance of the Illinois River for drinking purposes during those eight months without boiling and without filtering, and denominate it a potable water?

A. I would consider that water from the Mississippi River potable.

1474 Q. And you would so advise?

A. Yes, sir.

Q. Do you know any (scientist) that has given the question of running streams any consideration that hold that view?

A. That running water purifies itself?

Q. No; that streams' sewage polluted by cities nursing their banks are potable water?

A. Yes, there are some.

Q. Well, who are they?

A. Well, I cannot think of any just at this moment.

Q. Do you adopt their views?

A. No, sir.

The analytical results from the water, as I have studied them,

1477 the water of the Mississippi River found a few miles above the mouth of the Illinois, allow of no other conclusions than that the water is potable.

Q. Then you eliminate from your conclusion all considerations of the opinion of experts on bacteriology which you adopt in arriving at that conclusion, do you not?

A. I do not; because the study of bacteriological reports on the water from that point do not justify me in forming a general conclusion from a general hygienic standpoint, a conclusion that the water found in the Mississippi River above the mouth of the Illinois River is unpotable. There is no bacteriological evidence to show that

it is unpotable from a general hygienic standpoint in conjunction with the chemical potability found.

1480 Q. Well, in adjudicating opinions of different men, and arriving at a conclusion as to the weight of evidence, do you, Dr. Teichmann, adopt the principle of those men who hold that sewage contaminated streams are not potable?

A. I do adopt it for all cases where general conditions, as I have repeatedly mentioned to-day, are favorable to the application of such a rule; but they are not favorable in every case. I do not accept it as a hard and fast rule for every possible case, disregarding entirely the various conditions that should come into consideration.

Q. Do you know of any reason or condition that exempted the Mississippi River from Grafton to St. Paul from being within that rule; if so, what are they?

A. No, sir.

Q. Why not?

A. It is possible that the rule may be applicable to the Mississipi River above Grafton, providing that the conditions prevail that will justify its application.

Q. Do you know whether those conditions prevail or not?

1481 A. I do not know, as I said before.

Q. Are you testifying as an expert upon the facts that only apply to this case, doctor?

A. I am testifying to the facts as I found them at the mouth of the Illinois River. What the conditions are hundreds of miles above the mouth of the Illinois on the Mississippi I am now considering. I only ascertained the character of the Mississippi River water three and five miles above the mouth of the Illinois. Is it good or bad? And I found it potable, and I so expressed it. What it might have been miles and miles above the mouth of the Illinois is immaterial, to my mind, in considering the questions involved in the investigation that I conducted these years.

Q. Then, as far as your opinion goes to the potability of the water at the mouth of the Illinois, you have not taken into consideration the bacteriological view of the situation, have you?

A. Yes, sir; I have.

Q. And have you given it any consideration, any weight, in arriving at that conclusion?

1482 A. Yes, sir; I have.

Q. And, in view of that fact, that you are unable to state what the conditions of the Mississippi River are above Grafton bacteriologically, whether it is the exception or within the general rule,

that all sewage contaminated waters are not potable, still you adhere to the opinion that you take into consideration the bacteriological view as well as the chemical, and arrive at the conclusion that the water is potable?

A. Yes; I have examined both conditions chemically and bacteriologically and thereupon formed a conclusion that the
1483 water of the Mississippi is potable three and five miles above the mouth of the Illinois River.

Q. I want the conclusions of a bacteriologist who has made the analytical investigation, who concludes from his analytical investigations that the waters of the Mississippi River are potable, and whose opinion you approve.

A. Well, I have no definite conclusion to that effect; because I formed my own opinion from the study of analytical data.

Q. Then, you know of no bacteriologists whose views you accept that hold that the waters of the Mississippi are potable above Grafton?

A. No; I form my own opinion from the data.

Q. Notwithstanding that fact, and the fact that you have never made a bacteriological survey of the waters of the Mississippi above Grafton, you still hold to the opinion that the waters of the Mississippi are potable?

1485 A. From the study of analytical data of the bacteriological investigations I feel justified in answering that question, yes.

Q. Then, is it not a fact, doctor, that bacteriologists have condemned the waters of the Mississippi River above Grafton?

A. Not to my knowledge.

Q. Is it not a fact that Dr. Ravold, the bacteriologist, a recognized authority in St. Louis upon bacteriology, condemned the waters of the Mississippi River as not being potable?

A. Not to my knowledge.

Q. Assuming that he did so testify, would that have any effect upon your conclusion as to the potability of the waters of the Mississippi at Grafton?

A. I would base my final conclusion upon the study of analytical data that have been obtained from the bacteriological investigation of the water at that point.

Q. Then, you would not regard the opinion of a man who has given this question a great deal of study as having any weight upon you in arriving at a conclusion as to the potability of the waters of the Mississippi bacteriologically?

A. I would give considerable weight to the conclusions of a

bacteriologist upon certain analytical data that he is investigating or from which he is drawing his final conclusions, but I would not accept his conclusions unless I would have convinced myself from a personal study of those very analytical data whether, in my opinion, when judging the general potability of a water, whether his conclusions would conform with my final conclusion, from a general hygienic standpoint.

I have studied the analytical data which were at hand at the point several miles above Grafton. This data is sufficient, to my mind, to enable a general conclusion from a hygienic standpoint to pass upon the potability of the water of the Mississippi River
1486 above Grafton for a period of one year from September, 1899, until October, 1900.

Q. So that it comes right down to the point that you have got to accept the judgment of some other man before you can pass a judgment yourself, bacteriologically; is not that right?

A. In a measure, yes.

Q. Well, is not that in a full measure?

A. Well, he won't form an opinion blindly. He will examine those data and from the general course pursued in obtaining those data, together with the personal opinion that he has of the reliability of that man as a scientist to conform to the opinion.

Q. Well, that would leave it to the man's judgment, would it not?

1488 A. Yes, that altogether would make up the judgment.

Q. If that man is wrong in his conclusions and analyses, you are wrong in your conclusions, are you not?

A. Not in all cases. He may draw different conclusions from the very data than I would draw.

Q. And the data to which you are speaking, was that the data that Dr. Ravold introduced in evidence here in connection with his testimony?

A. Yes. As far as I know, I have drawn certain conclusions from those data which are my own conclusions.

Q. Then, I say, if Dr. Ravold, up at Grafton, should draw the conclusion from the analytical data which you have inspected, that running water in the Mississippi River which is sewage polluted is not a potable water during twelve months of the year, you differ with him?

A. If Dr. Ravold meant to apply that to every case analytically—

Q. No, I mean at Grafton.

A. At Grafton, as compared with the chemical results, I have already stated that from a general hygienic standpoint I would consider the Mississippi River water potable.

Q. Doctor, I did not ask you what you considered.

A. I never considered it alone.

Q. I ask you if Dr. Ravold drew the conclusion that the waters of the Mississippi River were not potable, from the data that you say you have inspected and analyzed, do you differ with him as to his conclusions? Cannot you answer that, yes or no?

A. Well, that depends upon the point to which he applies that conclusion.

Q. At Grafton. At the point where the samples were taken. At Grafton.

A. I formed my conclusions—

Q. I did not ask you that, doctor. Do you understand my question?

A. Yes, sir; I do.

Q. Then, cannot you answer it?

A. I am beginning to answer it.

Q. The question is, whether, if Dr. Ravold drew a conclusion from the data that you say you have inspected—

A. Yes, I have.

Q. Up there at Grafton. That the water of the Mississippi was not potable, do you differ with him in his conclusions from that data?

A. According to my opinion that the water is potable at Grafton, I do.

1490 Q. You do?

A. Yes, sir; I do; viewed from a general hygienic standpoint.

Q. Well, if it should appear that the sewage of St. Paul and Minneapolis and all the other cities above Grafton empty their sewage into the Mississippi River, and that that sewage came from a great many thousands of people, how could you explain the potability of the water at Grafton during the entire year, if those facts, which are assumed, are facts?

A. I would not express an opinion except by my personal investigation of the analytical data that might be presented to me from reliable chemical authorities on the character of that water above a point from where I took the samples.

Q. So that you are unable to give an opinion or express a reason why the sewage contaminated waters of the Mississippi are purified and rendered potable during the entire year, when it reached three miles above Grafton?

A. It would be unfair for me to give an opinion on that
1491 question without personal investigation and study of analytical data.

Q. You have no opinion, then, as to how this condition above Grafton is obtained?

A. Nobody could form a fair opinion.

Q. I am not speaking of anybody, doctor; I am asking for Dr. Teichmann's opinion.

A. Well, I have no opinion.

Q. You have no opinion on that subject?

A. On that subject.

Q. And the situation that presents itself, of the potability of the water above Grafton, is a condition that you have no explanation in your mind to offer for?

A. I did not study it, and, therefore, have no opinion to express.

Q. Have you any ideas on the subject, doctor, as to why that water is potable for the year around above Grafton?

A. I would not form any ideas without a thorough investigation.

Q. Does the theory that running waters purify themselves of sewage contamination, running over the course from St. Paul down to Grafton, appeal to your judgment as an experienced man upon water courses?

A. I could not express an opinion without previous investigation.

Q. Now, doctor, have you examined what is the condition of the Missouri River water above its mouth as to potability?

A. I consider the water potable at Fort Bellefontaine, the station in the Missouri River where we collected samples of water.

Q. Where is Fort Bellefontaine, doctor?

A. Fort Bellefontaine is five miles above the mouth of the Missouri River.

Q. Is that water potable all the year around?

1492 A. More or less potable all the year around.

Q. During a year, how many months of the year are the waters of the Missouri potable; and how many months of the year are waters of the Missouri not potable?

A. I would consider the water found at Fort Bellefontaine station potable throughout the year.

Q. Will you name to me the cities that empty their sewage into the Missouri River?

A. I could not give you that list, because there are a great many. It is a very long river.

Q. Well, beginning at Sioux City; that empties its sewage into the Missouri, does it not?

A. I believe it does.

A. Omaha empties its sewage?

A. Yes, sir.

Q. Omaha has large packing industries there, has it not?

A. Yes, sir.

Q. And large distilling interests in Omaha?

A. Yes, sir.

Q. And across the river from Omaha is the town of Council Bluffs, which is quite a manufacturing town, is it not?

A. I understand it is.

Q. They empty their sewage into the Missouri River, do they not?

A. Yes, sir.

Q. And, coming down a little bit further, is the town of St.
1493 Joseph, or St. Joe; that empties the sewage into the Missouri, does it not?

A. Yes, sir.

Q. And Atchison, also, and Kansas City?

A. Yes.

Q. That is a city of considerable size, is it not?

A. Yes.

Q. Great industries in the packing business and slaughtering business there?

A. Yes, sir.

Q. It has distilleries, too?

A. Yes, sir.

Q. And other manufacturing industries; and the sewage of that city empties into the Missouri River?

A. Yes, sir.

Q. And then the towns that lie along both sides of the river in Kansas?

(MR. JEFFRIES: I object to all the questions, and move that they, together with the answers thereto, be stricken out as far as the same refer to the emptying of the sewage of the various cities into the Missouri River, for the reason that the same are incompetent and irrelevant and have no bearing upon the controversy here involved; and for the further reason that those towns situated upon the

Missouri River discharge their sewage into a natural water flow and flow into the water shed tributary to the Missouri River, while the question here involved is that the sewage from Chicago is carried over from one water shed into another from the Chicago River, or Lake Michigan
1494 rather, into the water shed of the Illinois River and from thence into the Mississippi River.)

Q. And the sewage of Jefferson City, the pride of Missouri, empties into the Missouri River, does it not?

A. Yes, sir.

Q. Now, doctor, are there any other cities that you know that I have not enumerated that empty their sewage into the Missouri River?

A. Yes, sir. I think you have omitted Herman, Missouri, and St. Charles, Missouri.

Q. Can you explain to me why the Missouri River at Fort Bellefontaine is potable when all these cities and towns that have been mentioned here empty their sewage into the Missouri River?

A. First of all, it depends very much upon the amount of sewage which these cities discharge into the Missouri River. It depends, furthermore, upon the volume of water in the Missouri River. It depends, also, upon the velocity of the flow. It denepds, also, upon the general conditions of the course of the Missouri River; it depends largely upon what accessions of soil in the form of clay and silt the Missouri River takes up along its winding course, with innumerable curves and bends, drags along into the river, and what effect sedimentation of this enormous quantity of soil which is by the erosions of the land carried into the water will have on the sanitary character of that water.

Q. Doctor, does a stream running east and west purify itself any better than a stream running north and south?

A. I do not see any difference there.

Q. What conditions obtain in the Missouri River for its purification that do not obtain in the Mississippi River above Grafton?

A. The Mississippi River above Grafton I am not familiar with, except at a point from three to five miles above the mouth of the Illinois, so I could not make a comparison there.

Q. What conditions obtain in the Missouri River that do not obtain in the Illinois River?

A. There are various conditions. The volume of water in the Missouri River is generally larger; the course that the Missouri River takes is one of a great many bends and curves—much more so

than the Illinois River does. The quantity of suspended matter as found by the analyses of the waters from the two rivers is much larger in the Missouri River than it is in the Illinois River. There are, as I have already said, enormous accessions of soil swept
1495 along the course of the river from the shores of the river into the Missouri River. This is not the case with the Illinois River.

Q. What effect has suspended matter in water upon the purification of sewage pollution?

A. That depends very much upon the character of the suspended matter.

Q. Does clay in suspension act as a purifier?

A. Heavy sediments of clay will produce at such points along the river where the velocity is slow along the shores of the river, and not in the channel, will produce, particularly if there are many bends and curves, considerable sedimentation along the banks. The Missouri River is a river that is very poorly regulated. It is a river whose banks often overflow.

It is a river that is practically being abandoned, and there is considerable overflow at times, and this overflow will cover vast areas of land sometimes. * * *

It helps the purification, because sedimentation, according to the accepted axiom of modern science, will assist in purification. * * *

The area of land overflowed along the Missouri river—I cannot give you any accurate data on that point. * * *

They prevail, from my own observation along the Missouri,
1496 from Kansas City to St. Louis.

I have seen at places along the route of the Missouri River—I have seen as much as 40 or 50 acres overflowed on one side of the stream. * * *

Since these conditions prevail all along the route between Kansas City and St. Louis, I should think it would have a considerable effect.

Q. Do you consider that a great effect in the purification of the Missouri River, these sedimentation beds operated by the overflow of the banks?

A. Yes, sir.

* * * At some places these points of sedimentation are covered with water that stagnates for some time, and the natural processes of sedimentation there will drag down to the bottom of those sedimentation beds a great deal of organic matter, and this organic matter will undergo nitrifying processes of purification more rapidly

because of nitrifying organisms, so-called bacteria, that per-
1497 form this oxidation work in the soil.

Q. And can you give any reason why this sewage becomes purified and the water rendered potable when it gets to Bellefontaine?

A. Yes. I have a reason why the water at the point of Bell-
1505 fontaine is potable, based upon investigations I made of the Missouri River.

Q. What are those reasons, doctor?

A. The length of the river; its many curves and bends; its many sedimenation beds along its course; and the long time
1506 water takes to flow all this distance from Kansas City.

The distance from St. Louis to Omaha by the water line of the Missouri River is 676 miles; from St. Louis to Kansas City is 403 miles; and the distance from Kansas City to Omaha is
1506 273 miles.

Q. Does that sewage from Kansas City purify itself in going 400 miles?

A. The chemical analyses of samples of water taken at Ft. Bellefontaine show that whatever water pollution—whenever sewage pollution has taken place from the sewage of Kansas City, that sewage pollution has to such an extent disappeared when the wa-
1507 ter reaches Ft. Bellefontaine. After a run of 403 miles that water is potable at Ft. Bellefontaine.

Q. How swift is the current in the channel of the Missouri River?

A. Do you mean the average?

Q. Yes, the average.

A. The average would be three miles, from three to three and one-half miles.

1508 Q. Per hour?

A. Yes, sir.

Q. Well, what is the velocity of the current of the Illinois River?

A. Well, I have been at times on the Illinois River when the current was one mile; and then again when it was declared to be two miles an hour; but not from my own measurements or investigation.

Q. Do you know of it ever having been over two miles an hour?

A. I think so.

Q. How much faster than two miles an hour have you known the current to be?

A. Well, at times of high water I have known that it was three miles an hour.

Q. In times of high water in the Missouri how fast is the current?

A. The current can go up at high water to three and a half and, possibly, four miles an hour.

1509 Q. Four miles per hour?

A. Yes, sir.

Q. Then, how can you state that the waters of the Missouri River are all the time potable in view of the fact that when the current of the river is four miles an hour, and it is only 403 miles from Kansas City to St. Louis, which, at that rate, would be four days for the sewage to get from Kansas City to St. Louis, that the water is potable?

A. I can only form the conclusion that the water is potable from the chemical analyses performed upon the water taken
1510 from the Missouri River at Ft. Bellefontaine, and the water was potable.

Q. How long would it take water to come from Kansas City to St. Louis running at the rate of four miles an hour?

A. I can only make an estimate of the current of the channel.

Q. Well, in the current?

A. The regular channel? How long it would take the channel water to come down at that rate?

1511 Q. That is what I mean.

A. Well, four days as you say.

Q. Well, now, if the sewage goes into the channel at Kansas City in any large quantities from the slaughtering houses there, wouldn't it be completely destroyed by the time that it got to St. Louis, if it only took it four days to go?

A. It would depend very much upon the quantity of sewage that would go into the river. It would depend upon the weather conditions. Whether it was warm weather, that would facilitate the processes of oxidation; and there would be a great many circumstances that would go into consideration to determine whether
1512 that sewage, after running four days at four miles per hour, would purify itself. It would depend very much upon the circumstances.

MR. JEFFRIES: I move to strike out all the testimony in reference to the water in the Missouri River which has been introduced,

for the reason that it is immaterial and has no bearing upon the issues in the case; and I move to strike it out for all purposes
1512 except as to the effect it might have upon the competency of the witness.

Q. Well, what are in the feces?

A. The feces are also composed of organic compounds principally.

Q. What are they?

A. Formed from the elements that I have already mentioned, carbon, nitrogen, hydrogen and oxygen, together with other compounds represented and coming from other elements.

Q. To be specific, what chemical elements or compounds are
1515 in the feces different from those four compounds of nitrogen, hydrogen, oxygen and carbon?*

MR. TODD: Do you want to pass upon the questions that are asked you, as to whether you will answer them or not, Doctor?

MR. JEFFRIES: That is an objectionable question, and I will permit him to answer without objection.

WITNESS: I will refuse to answer the question, as I said before.

MR. JEFFRIES: Name them.

WITNESS: No; I will not name them. I refuse.

All of which is found on pages 1515, 1516, 1517, 1518.

Q. Doctor, from the known composition of slaughter-house sewage and household sewage, which, in your opinion, will oxidize or purify itself more rapidly?

A. It is difficult to determine.

Q. Have you any opinion upon the question?

A. No, sir.

Q. If in suspension there was more (albuminoid ammonia) than is found in solution, what does that indicate?

A. If there was more in suspensions than in solution, it would indicate organic matter due to contamination of vegetable origin.

Q. Why not animal origin, Doctor?

A. Because the organic contamination of animal origin is more represented in the albuminoid ammonia in solution.

Why?

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*At this point of the investigation the witness refused to further answer questions on the ground that they were elementary, and that he had passed an examination upon them at some previous time; on the ground that it was fundamental knowledge and that he would refuse positively to answer questions. At the suggestion of Mr. Jeffries, "Go ahead and answer that question," the witness answered: "I refuse to answer that question." The Commissioner instructed the witness to go ahead and answer the question, and he still refused.

A. Because the organic matter of animal origin that is found in solution in the albuminoid ammonia will represent, to a large extent, the pollution of animal origin in soluble forms.

Q. If the albuminoid ammonia is in solution instead of in suspension to a high degree, what would that indicate?

A. Well, that will enable the conclusion that the origin of the organic matter may be more from animal sources.

Q. In what condition would you find the albuminoid ammonia from the sewage of slaughter houses—in suspension or in solution?

A. Well, in both, very likely.

1519 Q. Which would prevail more largely?

A. In suspension.

At times the albuminoid ammonia would be larger in suspension than the albuminoid ammonia in solution; and at other times the reverse would show.

Q. If that is true, how would you distinguish between albuminoid ammonia of vegetable and animal origin?

A. The distinction could be made from that point of view—

1520 that the organic matter in suspension is very largely composed of such matter as is of vegetable origin.

Q. And is there anything in the albuminoid ammonia itself that would enable the chemist to ascertain whether it came from vegetable or animal origin?

A. No, sir; not in the analytical product itself.

Q. In the Missouri River you found albuminoid ammonia in solution and in suspension?

A. Yes, sir.

Q. In different degrees?

A. Yes, sir.

Q. When albuminoid ammonia is found in suspension, does that indicate whether it is of animal or vegetable origin?

A. Well, that could not be determined from the analytical product itself.

Q. If albuminoid ammonia was in solution, would that indicate whether it was from vegetable or animal origin?

1522 A. Not if determined as found from the analytical product itself.

Q. Doctor, as a chemist, do you enunciate that as a principle of chemistry which you yourself by your analytical investigations have established—that albuminoid ammonia in suspension indicates vegetable origin and albuminoid ammonia in solution indicates animal origin?

A. I said that they may be present in both—not altogether in one.

Q. If they are present in each class, suspension or solution, how are you able to differentiate between albuminoid ammonia which is of vegetable origin and the albuminoid ammonia which is of animal origin?

A. Because I take into consideration the oxygen consumed results—the oxygen consumed results enable in a measure an
1524 opinion as to the vegetable or animal origin or whether the vegetable or animal matter prevails in that albuminoid ammonia.

Q. Doctor, is chemistry an exact science?

1525 A. It is supposed to ascertain facts only, and, therefore, is an exact science.

Q. Then, albuminoid ammonia in suspension does not demonstrate whether it is of vegetable or animal origin in itself,
1526 does it?

A. Not if you take the albuminoid ammonia analytically—the result by itself.

Q. If you knew, independent of chemistry, that the water was sewage, contaminated from the sewage of man or animal, then the nitrites appearing there you would draw the conclusion that they came from animal rather than vegetable origin, is that correct?

A. Yes, sir.

Q. If you did not know the origin, but only had the nitrites to go upon, could you tell whether it was of vegetable or animal
1528 origin?

A. No, sir; not if I took the nitrite results by themselves I could not do it.

Q. What do chlorines in a river indicate?

A. They may indicate sewage pollution or they may indicate the passing of a river through a deposit of salt in the geological structure.

Q. So that it is uncertain what it indicates?

A. Yes, sir, for chlorines alone.

Q. For chlorines alone?

A. Yes, sir.

1530 Q. Chlorine is the only element entering into water from sewage that does not change its form?

Q. Does the sewage from all the cities upon the Missouri River entering into the Missouri carry with it sodium chlorides?

A. Yes, sir.

Q. In addition to that, you have testified about the Kaw River?

A. Yes, sir.

Q. Can you, as a chemist, distinguish between the sodium chloride which comes from the sewage from the sodium chloride which comes from the salt beds on the Kaw River, as you have testified?

A. No, sir; not chemically; no, sir.

Q. Did you take into consideration in drawing your conclusions as to the conditions of the Missouri River, as to its potability, the sodium chloride which entered that river from the sewage of all the cities along it?

A. In a measure, yes.

Q. In what measure, Doctor?

A. Well, there is a certain amount of chlorine found in the Missouri River above the mouth of the Kaw River. That is true; the analyses show that. And also a certain amount of chlorine is found in the Missouri River after the Kaw River empties into the Missouri River.

Q. And when it goes to Bellefontaine, were you able to state what percentage of the chlorine which you found came from sewage and what percentage came from the Kaw River?

A. No, sir.

Q. Whether the percentage from the sewage was larger than
1531 the percentage that came from the Kaw, are you able to ascertain chemically?

A. No, sir.

Q. What is the size of the Kaw River?

A. Well, I could not tell you.

Q. What is the volume of water?

A. I have no data at hand just now.

Q. Compared to the waters of the Missouri River?

A. I have no data at hand just now to answer that.

Q. Have you ever had any data at hand?

A. No, sir.

Q. Then, if the size of the Kaw River was smaller than the Missouri River, in comparison with the Missouri River, would not high chlorines in the Kaw River go down when it reached the
1532 Missouri River?

A. Yes, sir; they would.

Q. You had samples taken in the Kaw River?

A. Yes, sir.

Q. The size and volume of the Kaw you do not know?

A. No, sir.

1533 Q. And never did know?

A. No, sir.

Q. Would the Kaw River waters commingle completely with the Missouri River three miles below the entrance into the Missouri River, at the point where the sample was taken?

1534 A. That I could not tell; I have not made any observation of that kind.

Q. Doctor, in the absence of the known volume of the Missouri River and of the Kaw River, do you take into consideration the sewage contamination from Kansas City, Missouri, and Kansas City, Kansas, as to the chlorines?

1538 A. Well, I did not in this case.

I say that more accurate conclusions could have been drawn if all those facts could have been ascertained; and in conjunction with the fact of those high chlorines in the Kaw River, should have been taken into consideration.

Q. My question is, did you eliminate those three essential

1539 facts from your opinion or conclusion, did you not?

A. Yes, sir.

Q. Have you knowledge sufficient so that you could take that amount of sewage into consideration in order to ascertain the

1540 percentage of chlorine pollution in the Missouri River below Kansas City?

A. No, sir; I cannot.

Q. Can you state what proportion of the increase of chlorines

1541 below Kansas City is due to the Kaw River water and what to the Kansas City sewage?

A. No, sir; I cannot.

Q. Doctor, why did you not take into consideration the sewage from Kansas City in your conclusion in regard to chlorines?

A. I have no available data. I could not obtain them, and it would necessitate an investigation that I could not undertake at that time; and then, seeing or noticing the high chlorines in the Kaw River, and calculating on a natural increase of chlorines, and in a degree depending upon the Missouri River stages, I calculated that some effect of the Kaw River chlorines must be estimated for the Missouri River; varying more or less according to the stages of the Missouri River.

Q. Your inability to get the data of Kansas City? Do you consider that a justification for the elimination of the sewage of Kansas City from your consideration?

A. Not at all times.

Q. But in none of your investigations have you taken into
1543-1544 consideration the sewage discharged from Kansas City, have you?

A. I have not in calculating the chlorines of the Missouri River.

Q. And was it because you did not deem that essential for your consideration, that you did take it into consideration—the sewage discharge of Kansas City?

A. It was because I could not obtain the data.

Q. And not being able to obtain the data, you eliminated it entirely from your consideration, did not you?

A. I relied upon the condition of the Kaw River as found to justify an approximate conclusion.

Q. And eliminated the sewage from Kansas City from any
1544 consideration?

A. Yes, sir.

Q. Then you don't know what proportion of the chlorines below Kansas City came from Kansas City and what came from the Kaw River, do you?

A. Not from any investigation of the Kansas City sewage.

Q. Do you know from any investigation, the proportion of the increase of chlorines below Kansas City that is due to the
1545 Kaw River and which is due to Kansas City sewage?

A. How much of each I have not estimated.

Q. Or from any other information you have got, do you know?

A. Well, as applied to the conditions prevailing on those days that those samples were collected I could not tell.

Q. And you have no other source of information except the
1545 samples that were taken upon those days, have you?

A. No direct information.

Q. Can you state whether the chlorines that you found at Bellefontaine that ninety per cent. of it doesn't come from the sewage of Kansas City?

A. At low stages of the river, I think that it does not.

Q. I am not asking you about the stages.

1546 A. That ninety per cent. does not. It depends upon the condition of the river.

Q. The slaughter houses of Kansas City empty a great part of the sewage which turns into albuminoid ammonia, doesn't it, Doctor?

A. Yes, sir.

Q. That is sewage from animal and man emptied into the
1547 Missouri River above Ft. Bellefontaine, isn't it?

A. Yes, sir.

Q. You cannot tell whether the albuminoid ammonia found in the Missouri River, whether 50 per cent. is attributable to vegetable or animal origin, can you, Doctor?

1548 A. No; not by my calculation; getting it down to such figures.

Q. Then, when you stated in your testimony yesterday that the Missouri River was potable throughout the year, you eliminated from your consideration the four winter months during which animal contamination existed in the Missouri?

A. I am very glad you brought that matter up, because, if I said throughout the year I did not mean to say that; what I mean to say was prevailed during the year in taking the larger part
1557 of the year when I think the water is potable, but for those four months I do not consider it potable.

Q. Whenever the bacillus coli communis is found in water, what does the presence of that bacteria indicate?

A. The presence of that bacteria may indicate either sewage pollution, if corroborated by chemical analyses, or may indicate fecal discharges of fish.

Q. And if, bacterially speaking, the coli communis is discovered in water, and that water is well stocked with fish, its presence there could be as scientifically accounted for as coming from the fecal discharge of fish as from sewage pollution, could it not?

A. Yes, sir.

Q. And there is no way of telling from a scientific standpoint whether this coli is the result of fecal discharge of fish or of sewage, is there?

A. The investigations, so far as I have been able to inform myself, have not reached that stage yet where that point could be settled.

Q. Well, there is no mark or peculiar attributes of those coli bacilli that marks them, then, as emanating from the fecal discharge of fish as different from the fecal discharge of animal or man, is there?

A. Not to my knowledge.

Q. In getting your information as to the bacterial conditions
1559 of the Missouri River, what data have you consulted?

A. Dr. Ravold's data.

Q. From the data, as compiled by Dr. Ravold, in regard to

bacteria in the Missouri River, what conclusion do you draw from that data as to the potability of the Missouri River?

A. I consider the Missouri River potable during those eight
1560 or nine months that I have specified, as representing the warm season of the year. Potable at Ft. Bellefontaine.

Q. Do you know of any scientific man who has investigated the waters of the Missouri River who holds to the doctrine that it is potable, aside from yourself?

A. Well, if I understood the testimony of Prof. Keiser correctly, Prof. Keiser testified to that effect.

Q. He did not touch on the bacteriology of it, did he?

A. Well, you are speaking of potability. You did not specify bacteriologically.

Q. Well, but as applying it to bacteriology, I am examining you now as a bacteriological expert.

A. Well, bacteriologically—I mean to say from a bacteriological standpoint alone, a running river should not be judged as to its potability. The chemical conditions should be taken into consideration.

Q. Do you know of any other authority on bacteriology that holds that the Missouri River is potable—is a potable stream, aside from yourself?

A. Bacteriologically?

1562 Q. Yes.

A. No, I cannot call any to my mind just now.

Q. Then, the conclusion is irresistible that the sewage of Kansas City has become purified before it reaches Bellefon-
1564 taine in going a distance of 403 miles?

A. At certain times, when all of such conditions would prevail, I should say yes.

1585 A. Well, I do not admit sewage pollution at Ft. Bellefontaine from Kansas City or the stock yards.

Q. Then, if nobody knows what causes—if scientific men have not been able up to the present time to give an explanation of that condition of purification, have they?

A. They can give an explanation from studying the general
1587 conditions prevailing in the Missouri River between Kansas City and Ft. Bellefontaine.

Q. Then, what do you mean, Doctor, by stating that no one could tell the causes of purification?

A. Because scientific researches have not been made to the extent of analytical survey of the entire route from innumerable

points between Kansas City and St. Louis, and, therefore, an opinion may be formed on the question of what becomes of the Kansas City sewage would be based upon the general conditions prevailing in that river between Kansas City and St. Louis, as described in my testimony previously, from which general conclusions may be drawn as to what becomes of the Kansas City sewage.

Q. It is problematical, is it?

A. Yes, sir.

Q. No scientifically ascertained results have at present been achieved?

A. It is problematical; yes, sir.

Q. But it is not problematical what becomes of the sewage of Chicago, is it, Doctor?

A. The conditions——

Q. Answer the question, Doctor.

A. The Chicago sewage is entirely different.

Q. Has the light of scientific truth shone more clearly upon the chemical and bacteriological mind in regard to the Chicago sewage than that of Kansas City sewage?

A. The conditions of the two rivers are so materially different. The quantity of sewage coming from Kansas City being discharged into the river is so materially different from the sewage being discharged from Chicago into the Desplaines River. The conditions of the Desplaines River and the Illinois River vary so much from the conditions prevailing in the Missouri River. The distance between Chicago and St. Louis for the sewage to run is 357 miles, and the distance from Kansas City to St. Louis, 403 miles.

Q. Making how many miles difference?

A. Forty-six miles.

Q. Have you any personal knowledge of the quantity of
1588 sewage from Kansas City that empties into the Missouri River?

A. I have not got the data at hand.

Q. Do you know how much sewage enters the Missouri River from the Kansas City stock yards and packing houses?

A. I do not know at this moment, because I have not got the data at hand upon which I can base the customary calculations.

Q. Have you ever been in Kansas City, Kansas, where the slaughter houses and packing pens and cattle sheds are located?

A. I have been in Kansas City, Missouri.

1589 Q. I am asking you about Kansas City, Kansas.

A. Not in Kansas City, Kansas.

Q. Do you know how much sewage comes from the slaughter houses?

A. That is impossible to know, unless one examines the respective slaughter houses and makes personal estimations and personal examinations on the spot.

Q. That you have not done, have you?

A. I have not done it, no, sir.

Q. Have you in your mind now, Doctor, any definite amount of sewage that enters the Missouri River at these points?

A. Not at this moment; that data I prepared some time
1590 ago. I haven't got them at hand now. I cannot recall them at this moment. It is impossible to do that.

Q. Do you know the number of cattle that are slaughtered per day?

A. I could not tell you at this moment.

Q. I mean Kansas City, Kansas.

A. I had those data at hand, but I haven't got them in my memory just now.

Q. Have you estimated it at Kansas City, Kansas?

A. Yes, sir.

Q. What is the purpose of making that estimation, Doctor?

A. The purpose of that estimation was to ascertain how much sewage enters the Missouri River, in accordance with the customary estimation, from Kansas City, Missouri, and Kansas City, Kansas.

Q. What did you want to know that for, Doctor?

A. To find out how much sewage these cities discharged into the Missouri River.

Q. After you found that out, what use did you make of it?

A. Well, I studied the conditions of the Missouri River, and I utilized the data in the customary way such conditions are studied.

Q. When you made your analyses below Kansas City, Missouri, why did not you take into consideration the volume of sewage that you have testified to having at one time estimated in considering the chlorine test at that point?

1591 A. I did not consider the chlorines; I considered the sewage as such.

Q. My question is, why didn't you take into consideration in ascertaining the source that chlorine came from the sewage of Kansas City, Kansas, and Kansas City, Missouri, when you made the test below Kansas City?

A. Because it is difficult to estimate from the volume of sewage discharged into that river the quantity of chlorine.

Q. Is it any more difficult to estimate the quantity of chlorine below Kansas City that enters that river from the sewage of Kansas City, Missouri, and Kansas City, Kansas, than it is to estimate the amount of chlorine that comes from the Kaw River population of Kansas City?

A. That is a different proposition. The chlorine in the Kansas River is estimated and analyzed by taking a sample right from the river and analyzing it, the quantity of chlorine, to find out how much chlorine is contained in the sewage discharged from the City of Kansas City is extremely difficult; because there are a number of sewers there and the water has to be taken out of the sewers and tested, and then you have to approximate which may not be sufficiently reliable to be used as data, establishing how much chlorine there is in the sewage coming from all these sewers.

Q. Was it because of the difficulty in obtaining those facts that made you eliminate the sewage of Kansas City, Missouri, and Kansas City, Kansas, in ascertaining the chlorine below Kansas City and attributing it to the Kaw River?

A. I did not eliminate the sewage of Kansas City in passing an opinion on the chlorines as compared in the Kaw River and found below Kansas City.

Q. How much of the chlorine that you discovered in your analyses below Kansas City was attributable to the sewage from Kansas City, Kansas, and Kansas City, Missouri?

A. That is the question which I yesterday answered, that I could not tell, because I had not made investigations as to the
1592 quantity of chlorine to be found in the sewage discharge from various outfalls into the Missouri River—because of the extreme difficulty in estimating the amount of chlorine there.

Q. Dd you read anything about the building of that canal in the newspapers of St. Louis at the times that the bills were passed in the Legislature of Illinois, at Springfield?

A. Well, that is prior to 1890, is it not?

Q. Yes, 1889.

A. 1889? No, sir; not at that time.

Q. And from 1889 on to 1893 or 1894, was anything said about the Drainage Canal and its construction in the papers of St. Louis, that you know of?

A. Yes, sir. The matter was discussed in the year 1893 to some extent.

Q. It was a matter of general knowledge then in St. Louis that this improvement was being made at Chicago, was it not?

A. Yes, it came up before the Board of Health in the form of discussion of a resolution introduced in 1893.

Q. And who introduced the resolution, Doctor?

A. I believe the Health Commissioner of St. Louis at that time.

Q. Have you a copy of that resolution?

A. I haven't it on hand just now, but it is published in the annual report of the Health Department for that year. I could produce it.

Q. Could you state in the absence of the resolution (which I should like to have you produce) the contents in substance of what that resolution was?

A. Now, as far as I can recollect it, this is quite a long time ago, there were several resolutions. One resolution was that in view of the construction of the drainage canal at that time going on in Chicago—

Q. That was in 1893, was it?

A. Yes—a national board of experts should investigate that question as far as it would affect the water supply of St. Louis, and questions in general pertaining to sewage pollution. The Board of Health recommended in the resolution either that Representative Barthold of St. Louis, in Congress, should introduce a measure asking for such an investigation, or that such a measure had already been introduced by Mr. Barthold, and was supported by this resolution. The other resolution was calling upon the City Chemist to perform some analyses of samples of water. He was to collect them
1599 from the mouth of the Illinois down to the City of St. Louis at that time—from the Mississippi River and the Illinois River.

Q. Can you secure for me the copies of those resolutions and
1600 the recommendations of the President of the Board of Health to the Mayor?

A. Yes, sir.

Q. Could you take a gallon of that water in the channel of the Mississippi River and tell how much of that water was Mis-
1618 souri River water, how much Illinois River water and how much Mississippi River water?

A. No, sir; not that way.

Q. How much of the year do the waters of the Mississippi River and the Missouri River enter the Intake at the Chain of Rocks?

A. The variations are so great there from day to day that a general deduction as to how many days during the year, or for how

long a period the mixture of the Mississippi and the Missouri enters the Intake, is difficult, unless we apply chemical results as found in the analyses of waters collected from the Mississippi River at
1620 Hartford, from the Missouri River at Ft. Bellefontaine, and from the Mississippi River as it enters the Intake.

Q. Well, is there anything—any substance in the sewage discharged into the drainage canal at Robey street that are dangerous to the health as ascertained by you as a chemist?

A. The chemical analyses alone, not considering the bacteriological analyses.

Q. I have asked you to leave out the bacteriology.

A. The chemical analyses alone would not reveal that.

Q. Do your chemical analyses reveal anything in the discharge of the Chicago sewage into the Drainage Canal as being harmful to health?

1623 A. I did not reveal anything directly; but general conclusions as to the potability of that water would result in a different opinion.

Q. Have you examined the tables that have been prepared on bacteria and introduced here in evidence.

A. Yes.

Q. Did you draw any conclusions from these tables?

A. Yes.

Q. Do you know whether or not they disclosed any pathogenic bacteria as being present in the sewage at Robey street in the canal?

A. Yes, sir.

Q. Was there any pathogenic bacteria in that sewage?

A. Yes, sir..

Q. What were they?

A. There was coli communis found.

Q. Was the coli communis a pathogenic germ?

A. The coli communis being an important factor in some diseases.

Q. My question, Doctor, is, is it a pathogenic bacteria?

A. I consider it in a measure a pathogenic bacteria.

Q. In what measure?

A. In so far that it may be harmful in water to some people; to some individuals; that it may be harmless in water taken by other people.

Q. Does the coli communis become harmful when taken in-
1624 ternally?

A. Some intestinal diseases are ascribed to the presence of coli communis.

Q. What sewage would oxidize more rapidly—that from slaughter houses or the fecal and urine discharge of man?

1627 A. I could not tell you, because I have made no special research in that line.

Q. What is the extent of organic pollution from the Peoria distilleries and glucose works, Doctor?

A. I have not made an accurate scientific estimate of that so that I could not answer that question.

Q. Don't you deem that important to be ascertained, in order to arrive at a correct conclusion as to the contamination of the Illinois River below Peoria?

A. As far as the analytical results of the examination of water taken from points in Illinois above Peoria, near Peoria and below Peoria, are concerned, that question indirectly came into consideration.

Q. Have you any data as to the amount of that sewage as to

1630 volume and weight?

A. No, sir; not as to volume and weight.

Q. What is the effect of this material in oxididation (Peoria sewage)?

A. This material, in the course of time, will undergo certain changes—chemical changes—and will disappear in the run of the river into which it is discharged.

Q. Will it oxidize more rapidly or more slowly than household sewage?

A. Well I could not tell; I have not made any investigation of that point.

Q. Does it (this refuse from distilleries) oxidize more rapidly than fecal matter or household sewage?

A. That I could not tell. But I have noticed in analyses that the disappearance of that swill was noticeable in running rivers.

Q. Give me an example of where that swill disappears and the sewage from distilleries disappears in running rivers.

A. At Peoria and at Pekin.

Q. If it disappears rapidly, did it disappear more rapidly

1632 than household sewage?

A. That I could not tell.

Q. Dr. Teichmann, I hold in my hand the Seventeenth Annual Report of the Health Commissioners of St. Louis. Will you state whether this is an authorized published copy of the proceedings of the Health Commissioners of the City of St. Louis?

A. It is the annual report of the Health Commissioners of St.

Louis for the fiscal year 1893 and 1894; beginning with April 1st, 1893, and ending with April 1st, 1894.

Q. I should like to have you identify certain parts of this report. On page 11 of this report there are two topics dis-
1633 cussed: Public water supplies and Illinois River pollution.

A. Yes, in the introductory report of the Health Commissioners.

Q. This is correctly reported in this book, is it not?

A. Yes, sir..

MR. TODD: I offer page 11 of this report for identification.

MR. JEFFRIES: You do not offer it as evidence yet?

MR. TODD: No; I offer it for identification.

MR. WOERNER: You will not have to identify it, we will admit the identity of the book.

MR. JEFFRIES: That is all right, then. Of course, we won't admit its relevancy or competency. If it will serve your purpose, we will admit that it is what it is. We will make that admission for you at any time you want, as far as the admission is con-
1634 cerned.

"I made analyses in 1893 of the Illinois River by order of the St. Louis Board of Health."

Q. Now, in the examinations that you made of the water samples taken in 1893, what was the condition of the waters of the Illinois River?

A. The condition of the water of the Illinois River as demonstrated by the analytical results showed the presence of or-
1635 ganic matter as evidenced by free and albuminoid ammonia the presence of nitrites to some extent, and the presence of high chlorines. Proved contamination of the Illinois River at the mouth.

"I stated at the time that the pollution found in 1899 was of a character indicating sewage pollution in the Illinois River."

"One of the conclusions was, that the Illinois River at its mouth was badly polluted during the entire period of investigation, from September, 1899, until the middle of January, 1900.

1636 Q. Before the opening of the canal?

A. Yes, sir..

Q. And in that investigation, did it demonstrate conclusively the character of the pollution, as to whether it was sewage or
1637 vegetable?

A. Well, in my opinion was that it was sewage pollution.

Q. From that analysis you concluded that the Illinois River, as it enters the Mississippi River, was a sewage contaminated stream, did you not; and the waters were not potable?

1640 A. I did; taking into consideration the reports of Professor Long and Professor Palmer as to the condition of the entire Illinois River valley.

Q. Have you any idea of the number of acres of low land between those points that the sewage-laden water of the Drainage Canal run over before arriving at LaSalle?

A. No, sir; I have no idea to that effect.

1643 Q. Have you any idea or any opinion or any information of any kind in regard to those conditions?

A. I have nothing definite in that direction.

Q. Have you any idea, doctor, how many thousands of acres

1646 of land, in the form of marshes, are along the course of the Illinois River?

A. No, sir.

Q. Wouldn't the water become impregnated with vegetable contamination in going over the overflowed marshes of Illinois?

A. Certainly; that part of the water that would overflow those large areas of land, that would be impregnated with vegetable matter.

Q. And what it would lose in sewage pollution it would gain in vegetable pollution to a certain amount, would it not?

A. Yes, if that land had vegetation it would necessarily receive accessions from that source.

Q. And vegetable pollution would manifest itself by the presence of albuminoid ammonia, would it not?

A. Yes; and, also, in the color of the water and sometimes as found in the odor of the water.

Q. Did you make any investigations to ascertain the dimen-

1647 sions of Lake Peoria?

A. No, sir.

Q. How large a lake is Lake Peoria?

A. I could not tell you now; I only know that it varies very much in size; and I have not any data at hand just now as to the size of that lake at those various times.

Q. How swift is the current through Lake Peoria?

1648 A. I could not tell you; I have no data at hand.

Q. Do you know the source of the Kankakee River?

A. No, sir.

Q. Well, did you get any specific information in regard to the

number of acres along the Illinois River that was overflowing marshes or farm lands?

1649 A. No, sir; except that there are general conditions which I familiarize myself with from the literature published on the subject.

Q. Do you know how much sewage from LaSalle is discharged into the Illinois River?

A. The sewage from LaSalle would be inappreciable.

Q. Do you know how much in volume was discharged into the Illinois River from the Sangamon?

A. Do you mean to say, how much water or how much sewage?

Q. How much sewage? Water is not contaminating in itself unless it has sewage pollution.

A. No. At low stages of the Sangamon River the sewage coming from that river would be inappreciable, and hardly
1659 have an effect upon the general chemical character of the Illinois River.

Q. Well, does the Kankakee River contaminate the waters of the Illinois River?

A. I think it does some; and at a times a little; but there is always some contamination there.

Q. Always some. But is it enough to affect the potability of the stream itself?

A. No, sir; because the analyses received from those tribu-
1660 taries showed that those tributaries are in a much better sanitary condition than the Illinois River.

Q. Now, eliminating the sewage of Chicago from the Illinois River, the sewage of Peoria entering that river would not be chemically discernable when it got to Grafton, would it?

A. The effects of that polution would not be chemically discernable at Grafton.

Q. Now, doctor, if your statements are properly based on investigation, and if you properly state the conditions of the Illinois River and its tributaries as to pollution, will you explain to me how it was in 1899, before the opening of the Drainage Canal, you reported to the Board of Health of the City of St. Louis that the waters of the Illinois River at Grafton were contaminated and not in a potable condition, as evidenced by the report on file?

A. Because I found the water of the Illinois River above
1662 Peoria badly polluted.

Q. In 1899, before the Sanitary District Channel was opened, you made analyses under the direction of the Board of Health and

the samples that were made were 19, taken three and five miles above Grafton; and from those analyses you reported the contamination of the Illinois River?

A. Yes, sir.

Q. Now, my question is: if the sewage of those cities purify themselves and the tributaries of this river (the Illinois River) do not pollute the Illinois River at Grafton, chemically speaking, how is it that your analyses in 1899, before the opening of the Drainage Canal, brought you to the conclusion of denominating that water a polluted water and not potable water?

A. Because my chemical analyses of the samples taken in the Illinois River a few miles above Grafton demonstrated the polluted character of that river at that point, and my investigation of analytical data furnished by Professor Long and Professor Palmer also showed that the Illinois River was badly polluted a few miles above Peoria. The explanation would easily be found in the conclusion that I drew, that the Illinois River was in 1899 a badly polluted stream throughout.

Q. Then, if your conclusions are correct, that the Illinois River was a badly polluted stream in 1899 throughout, why is it, then, that you conclude that the sewage of the cities along the banks, and the tributaries, do not contaminate the waters of that river at Grafton?

A. Because the Illinois River was badly polluted before it reached Peoria—before it passes those towns.

MR. TODD: I move to strike out the answer.

Q. Question repeated.

A. The Illinois River could be badly polluted and yet any pollution from its tributaries and from the towns along the Illinois River could be so inappreciable that it would not materially affect the character of that river. The river in its entire course was polluted in 1899.

1663 Q. The sewage of Chicago previous to the opening of the Drainage Canal did not enter the Illinois River, did it; or enter the DesPlaines River?

A. Yes, sir; it did.

Q. Haven't you testified that when the sewage from the Illinois and Michigan Canal was pumped into the Desplaines River, that it had been operated upon by conditions such as a septic tank would give, and that the sewage had almost disappeared?

A. Yes. I said that the preliminary stage of purification had been greatly facilitated by the conditions prevailing in the Chicago River and in the Illinois and Michigan Canal; but I never claimed

that it was not sewage any more when it was discharged from the Illinois and Michigan Canal into the DesPlaines River and the Illinois River at LaSalle. Why, that is still sewage as long as it is not purified in its entirety and has reached the final stage of nitrates.

Q. Do you hold now to the view that the pollution evidenced by your examinations in 1899 at Grafton, were attributable directly to this discharge into the Illinois and Michigan Canal by the pumping works at Bridgeport, Chicago?

A. It is my conclusion that the Illinois River was polluted by the sewage from the Illinois and Michigan Canal to some extent in 1899, certainly; and the analytical data shows that.

Q. And it manifested itself at Grafton?

1664 A. It manifested itself at Grafton by the bad condition that the Mississippi water was in at Grafton.

Q. How does the amount of sewage pumped into the Illinois and Michigan Canal compare with the amount of sewage from Kansas City, Missouri, at that time?

A. Well, I could not tell off-hand without making computations on the volume of water discharged from Kansas City into the Missouri River.

Q. What would be your opinion as to whether it would be more or less?

A. Well, that I could not tell off-hand, without—

Q. You have no information on the subject?

A. Well, I could form conclusions—conclusions made with customary computations of the relative figures of water supply and sewage of Kansas City.

Q. At present you have no idea as to the volume of the sewage?

A. Well, I could not form an opinion off-hand.

Q. Can you give any explanation, doctor, as to why the sewage of Kansas City, or the sewage contaminated waters from Kansas City entering the Missouri River, are purified by the time they get to Fort Bellefontaine, and that this sewage emptying into the Illinois and Michigan Canal, undergoing fermentation processes, such as would prevail in the Illinois and Michigan Canal, is not completely purified by the time it gets to Grafton, previous to the opening of the Drainage Canal?

A. Well, that is a rather sweeping question to ask, because a comparison between the two would have to be made, based upon like conditions prevailing at both places, which is not the case.

Q. So that the conditions of the Missouri River from Kansas

City to Fort Bellefontaine are so entirely different from the Illinois River from Lockport to Grafton that no comparison can be made?

A. The conditions are so different as to render a comparison difficult. I do not say that it is impossible, after carefully computing all the data that are at hand, and on the relative proportion of sewage to water supply, and the character of the sewage of the two places, and the water with which the sewage is mixed at the two places.

1666 Q. What is your opinion based upon? Your knowledge of the conditions prevailing in the Illinois River prior to the opening of the Drainage Canal, based upon your knowledge of the influence of a septic tank upon sewage and conditions prevailing in the Illinois and Michigan Canal, from Bridgeport to where the same enters into the Desplaines River, as to whether that sewage becomes purified in entering the Illinois River before it reaches Grafton or not, prior to the opening of the Drainage Canal?

A. Well, that is a very long question. I would like to have it reread to me slowly.

(Question read again.)

A. The conditions prevailing in the south fork of the south branch of the Chicago River, which is principally the feeder of the Illinois and Michigan Canal; furthermore, the conditions prevailing in the Illinois and Michigan Canal are such during the major part of the year that the preliminary fermentative processes of purification of sewage are facilitated in that river, as well as in the Illinois and Michigan Canal; yet the sewage, although in its ordinary course of purification—partly purified in its preliminary stage—yet this sewage requires considerable additional purification, the ordinary chemcial processes obtaining in this purification process, that it will require considerable time before the effects of this pollution on the Illinois River could disappear.

Q. Well, assuming all that, will it disappear by the time it

1667 gets to Grafton?

A. It is my opinion that it does not.

Q. Why is it that the sewage from Chicago, prior to the opening of the Drainage Canal, would not purify itself in running 350-odd miles, when the sewage of Peoria does in going less than 150 miles?

A. First of all, I don't concede that the sewage of Peoria purifies itself, from a general hygienic standpoint, during that distance.

Q. Do you assert, as a scientific fact, that it does not purify itself?

A. I only assert that the effects of the pollution of the Illinois

River from sewage of Peoria—the effects are not discernable in the chemical analyses, as far as chemistry is concerned, from the samples collected at Grafton, several miles above the mouth of the Illinois River, as far as chemistry is concerned.

Q. If that is true, doctor, what you have just stated, can you determine whether the sewage which you found at Grafton is Chicago sewage or sewage from Peoria?

A. The fact that the—

Q. Answer my question, doctor; yes or no.

(Question read.)

A. I can draw the conclusion from analytical data.

MR. TODD: Wait a minute. I move to strike out the answer and ask for a specific answer to my question.

A. Well, the answer—

MR. JEFFRIES: Read the question again.

A. It can only be ascertained what the effect of the discharge of Peoria sewage into the Illinois River is on the sanitary character of the Illinois River; that is the only thing that can be ascertained.

MR. TODD: I move to strike out the answer and ask for a specific answer to my question.

(Question read.)

1668 MR. TODD: My question is, can you determine?

A. The conclusion is justified that since the chemical analyses of the samples of water taken at a point a few miles above Peoria, the chemical character shows certain conditions of the Illinois River at that point; that after the introduction of the Peoria sewage into the Illinois River, before the Illinois River reaches Grafton, the chemical character of the water at Grafton is of a certain character, comparing that character with the character found in the water above Peoria, the conclusion is justified that the effect of the Peoria sewage on the Illinois River has disappeared; and the general pollution of the Illinois River as established above Peoria continues in a measure to the mouth.

MR. TODD: I move to strike out the answer and ask for a specific answer to my question.

A. Well, that is the only way that question can be answered.

Q. Read the question.

(Question read.)

Q. Now, can you determine by your analyses at Grafton, if what you stated before it true, Chicago as distinct from Peoria sewage?

A. That could not be done. Nobody could do that.

Q. And that includes yourself, does it?

A. Yes, sir.

Q. Suppose that the sewage of Peoria did not empty into the Illinois River, would the conditions that you found above Peoria of sewage become better in going as far as Grafton?

A. Well, that question would be hard to answer, because it would depend upon various conditions that have to be taken into consideration.

Q. Doctor, have you any prejudice against answering a question of that kind?

A. No, sir.

Q. Is there any reason that suggests itself to your mind why you cannot answer that question, as to whether the sewage above Peoria in the water, if the Peoria sewage was eliminated, would not become purified or improved by the time it got to Grafton, going 139 miles, I believe?

A. Since there is no such condition as you state prevailing
1669 in the Illinois River, I could not base any conclusions on actual conditions there. That is a strictly hypothetical problem.

Q. Yes, sir; have you any opinion upon it?

A. Hypothetically, I would then say, since the Illinois River showed such high pollution during its route from LaSalle to Peoria, and this high pollution being found throughout all our investigations, that, while the absence of sewage from Peoria might reduce that figure, it is my opinion, now, hypothetically, that the pollution of the Illinois River, without the addition of the pollution from Peoria, would prevail to a sufficient extent to still render that water, as found a few miles above the mouth of the Illinois, unpotable.

Q. Would it be to such an extent, to the same degree under those conditions as it would if supplemented by the sewage of Peoria?

A. Well, I have already answered that question; that I have said that, while there might be less of pollution noticeable at the mouth of the Illinois River, in the absence of pollution from Peoria, that still the pollution of the upper Illinois, before it reaches Peoria, being uniformly high, as found throughout all our investigations, this pollution would still prevail to a certain extent at the mouth of the Illinois, rendering the water of the Illinois River at its mouth unpotable.

MR. TODD: If the pollution above Peoria was eliminated, would the waters at Grafton be purified of the sewage of Peoria by the time it arrived at Grafton?

A. As I have already testified, if the Illinois River water, before

it reached Peoria, would be pure chemically, the effect of the pollution of Peoria sewage in the Illinois River would not be discernable at Grafton.

Q. Now, to what was that pollution attributable?

1671 A. I attribute that pollution to sewage pollution from the Illinois and Michigan Canal.

Q. Taking the sewage, that is, sewage unoxidized, when it enters the DesPlaines River or the Illinois River, do you know whether that amount of Chicago sewage when it enters the DesPlaines and Illinois rivers exceeded in volume the entire sewage of all the other cities and sections of the country that drain into the Illinois River?

A. At very low stages.

Q. Do you know, I ask?

A. Well, to—

Q. Whether it is greater or smaller?

A. To say that, accurate estimations would have to be made for certain periods.

Q. Well, for a year, say, do you know?

A. No, I mean for certain times, at low water stages, very low stages, on record, I think that that sewage coming from the Illinois and Michigan Canal would be larger than from the tributaries and from those small cities along the route.

Q. Has the stage of water anything to do with the volume of sewage?

A. Well, in measuring or in estimating whether the quantity of sewage there in those rivers—you have got to take the volume of water into consideration, because they mix.

Q. If a pound of fecal matter discharged is placed in 100 gallons of water, would you have any more sewage out of 100 gallons than you would if a pound was placed in 50 gallons of water?

1674 A. Well, the chemical analyses would show a different analytical result, and, consequently, a difference in the chemical character of those two sewages there after being mixed with so much water.

Q. Then, the chemical analyses would show more sewage in 100 barrels of water than it would in 50 barrels of water, would it not?

A. Well, it would show a larger volume of sewage-polluting water, that is all.

Q. I am not talking about volume of sewage-polluted water, doctor. I am talking about sewage that pollutes the water. Have you got the distinction?

A. Yes, sir. If you take—

Q. Now, do you know whether the quantity of sewage that pollutes water, that enters the DesPlaines and Illinois rivers from the Illinois and Michigan Canal was greater or less than the amount of sewage entering into and polluting the waters of the Illinois from its tributaries nestling along its banks?

A. That depends upon the stages of the river.

Q. Would the stages of the river indicate it, whether you know it or not?

A. The stages of the river would have to be taken into consideration in determining that point.

Q. If the river was two feet above its normal stage, would you know?

A. It would simply mean—

Q. Answer my question, doctor.

A. It would simply mean so much more dilution of that sewage.

Q. But would you know if it were two feet above or two feet below datum?

A. The chemical analyses would give me some information in that respect.

Q. I am not speaking about chemical analyses. I want to know if your knowledge of the subject depends upon the height or the depth of the water in the river?

A. It depends, above all, upon the chemical analyses of that water—the character of the water.

1674 Q. Is there any connection between the volume of the water and the source of your information in regard to that matter?

A. Well, if I want to draw any conclusions—

Q. I don't want any conclusions. I want to know whether you know or not.

A. Well, such a question could not be answered without taking into consideration the volume of the water into which the sewage is discharged.

Q. Then, you assert as a positive fact that unless you know the volume of water, you can't tell whether a thousand pounds of sewage polluting substance enter the water at the Illinois River from the Illinois and Michigan Canal, or whether five hundred pounds enter it from its tributaries, and cities outside of that source of pollution?

A. It would certainly require the consideration of the volume of water in that river.

1675 Q. Suppose that you take a pint of sewage and evaporate it down to the solids, and then add a pint of water to that prod-

uct that you have, would that put it back in the same condition it was when you first started?

A. No, sir; it would not.

Q. What would be lost?

A. There would be lost some matter that would have escaped during the process of evaporation.

Q. Can the matter be collected and weighed?

A. No, that is not done.

Q. Can it be done?

A. Well, a great many things are possible that are not done.

Q. Can a chemist do it, is what I want to know, doctor; or is that beyond the scope of chemistry?

A. Well, that is never done.

Q. Can it be done?

A. Well, you can determine that by a different method, by a method—

Q. Can it be done, doctor?

A. By distillation processes.

Q. Is there any reason why you cannot answer that question?

A. Well, it is never done.

Q. Can it be done?

A. Well, I presume it cannot be done.

Q. If you can ascertain that five pounds of fecal matter and
1677 urine discharge is placed in fifty gallons of water, would it change the five pounds by putting fifty gallons more of water into the fifty that it already contained?

A. The chemical results would vary considerably.

Q. But would the quantity in solution vary?

A. The quantity in solution would show different results.

Q. Would it be more or less than five pounds if you added fifty gallons of water?

A. Well, if you dilute it somewhat, the chemical results would show, of course, a smaller percentage.

Q. But would the amount increase or decrease by adding water?

A. The chlorines would show reduction by dilution.

Q. Would the amount increase or decrease by adding water, doctor?

A. Well, the amount itself—

Q. Would there be any more than five pounds of it if you added fifty gallons more of water?

A. If you added like amounts to like volumes of water, the
1679 amount added to the two volumes of water is alike, certainly.

Q. Now, could you, by any process known to chemistry, an-

alyze that water and state that five pounds of fecal and urine discharge had been put in there?

A. No, sir; I could not. I could only determine that sewage had been added to that and the chemical analysis would show a percentage of sewage ingredients somewhat corresponding to the
1680 original quantity of sewage added to that water and dissolved in it partly and partly not.

Q. Have you ever made any personal investigation as to the amount of sewage from Springfield, Illinois, that enters the tributary that leads to the Illinois River? Have you ever made an estimate?

A. The analyses from the Sangamon River suffices to demonstrate—

Q. You can go on and I will move to strike out the answer as not being responsive to the question.

A. Repeat the question.

(Question repeated.)

A. I made an estimate as to the effect of that sewage on the
1685 Sangamon River.

I made an estimation of the sewage at Pekin from chemical analyses, but what percentage I cannot remember now.

The quantity of sewage from Peoria I base on the water supply.

I do not know directly how many tons of sewage or refuse is drained into the Illinois River every day by the distilleries of Peoria.

I cannot give an accurate figure directly as to quantities and
1686 tons.

In 1899, in November, there was somewhat of an epidemic. There were 482 cases reported in November, 1899, of typhoid.

Q. Now, in the record of the Board of Health Department of the City of St. Louis, is there any month previous to that when as large a number of cases has been reported in one month?

A. Yes, in the year 1892, during that epidemic, ascribed to the Harlem Creek pollution above the old intake. I have not the data for that at hand now. They were considerably higher than those in November, 1899.

Q. Well, 482 cases in one month makes quite a responsible showing for typhoid, doesn't it, doctor?

A. Yes, sir.

Q. What was the cause of that typhoid fever?

A. Well, the true cause for that typhoid has never been ascertained, except that it has been ascribed to the polluted water supply.

No other reason than that has been found, to my knowledge,
1688 and that was before the opening of the Drainage Canal. Since the opening of the Drainage Canal there has not been 482

cases of typhoid in St. Louis in any one month. The condition of the public health of the City of St. Louis since the opening of the Drainage Canal has never reached the point in typhoid that occurred in any one month.

Q. From what data do you get the information that the Kaw River goes through a salt country?

A. Mineral resources of the United States, Calendar year 1887, U. S. Geological Survey; "A tabulated Presentation of Salt Deposits in the United States," published in this government publica-
1688 tion under the title "Useful Minerals of the United States; A partial list of ores, minerals and mineral substances. Industrial importance arranged alphabetically by states and territories, by Albert Williams, Jr.," etc.

1691 Description of Potable Water.

Q. Then, the standard of potable water—then, the moral to be drawn from what potable water is, "Give the people what they think they want" is the test, isn't it?

A. If it is not injurious to the public health. I would say it would depend upon the effect upon the general public health that the practical application of that standard would have. If the public health statistics show that the water does not have any injurious effect upon the public health, such water can be considered permissible.

Q. Doctor, have you ever formed an opinion as to whether the waters at New Orleans, after receiving the sewage discharge of the entire Mississippi Valley, is sewage polluted or not, or potable?

A. I have not given the analytical data obtained by other investigators on the chemical character of the Mississippi River water at that point any study.

MR. WOERNER: Why don't you say yes, doctor, and be done with it?

A. I won't say that. I have not studied the data, but I am not able to answer that question now positively or negatively.

Q. That's what he asked you—whether you know.

1693 A. I don't know.

Q. If water is unpotable, the addition of sewage renders it more unpotable, and if the people thought that they wanted to use that water and did use it, it would be potable for all practicable
1696 purposes, would it not?

A. You mean after the increased pollution. Yes, sir.

PROFESSOR EDWARD H. KEISER.

Re-direct Examination.

Q. Professor Keiser, I will ask you if you have made an examination from data furnished you by the Board of Health of the City of St. Louis of the conditions of the water supply of St. Louis subsequent and prior to and after the opening of the Chicago Drainage Canal?

1697 A. Yes, sir.

(Objected to.)

I obtained the data from the water commissioner of St. Louis, Mr. Edward Flad, and from the office of the city chemist, Dr. Teichmann. * * * These analyses are reported in the Mayor's message —the Mayor of St. Louis, annual message for 1894, page 418, and here are these analyses taken out of the Mayor's message for

1698 1894. * * *

In looking over the statistics of the Health Department of the City of St. Louis, I found eleven analyses of the water of the Missouri River, taken at a point above the mouth of the stream, are not recorded in the Health Department of the City of St. Louis.

1702 ### Cross-Examination.

Q. By whom were the 17 analyses from the distributing well made in the period ranging from May 2nd, 1893, to January 24th, 1894?

A. They were made by the water department of the City of St. Louis,—Mr. M. L. Holdman, water commissioner.

I obtained these figures from the annual report of the Mayor of St. Louis, from 1894, page 418, and here are these analyses taken out of the Mayor's message for 1894.

Q. Do you know as to any one of the samples in the paper I have in my hand, marked "Appendix I, Annual Report of the Water Commissioner for the year ending 1894, M. L. Holdman," what time of the day or any one of the days mentioned in the first paragraph of this table that the samples were taken, from what point and what time elapsed from the taking of the sample until these analyses were completed?

A. They were taken at the St. Louis intake, but I don't know what time elapsed after the taking until they were analyzed.

Q. As to any of these samples in the paper described in Group D and Group C, can you tell at what time they were taken from either of the distributing wells or from the clear wells, and how long a time

elapsed until they were analyzed after they were taken?

1712 A. No, sir. Except what I have read into that record. The method of the analyses is there described from the printed copy of the record.

Q. Can you form an opinion on the potability of a sample of water which has only, so far as your information is concerned, the following elements: Free ammonia .046, Nitrites .03, Albuminoid Ammonia 1.33, Nitrates .38; and, if so, what is that opinion?

A. Yes, sir; I should say that water was not unsanitary.

Q. Is it potable water?

A. Yes, drinkable water.

There is no distinction between potable and drinkable water.

1714 Q. You obtained the averages which you have given this morning by the use of the process of adding up the results of each sample and dividing it by the number of samples?

A. Yes, sir.

Re-direct Examination.

Q. Will you bring the book from which those pages are taken?

A. Yes, sir.

MR. JEFFRIES: Now, I will offer this page in evidence as Complainant's Exhibit No. 36, with the privilege Monday morning of introducing that page from the book of record of the Mayor in connection with the pages of the book as containing the system or plan used in arriving at these results.

1726 (Said paper received in evidence and marked as requested.)

(Objected to.)

1726 J. L. VAN ORNUM.

Direct Examination.

Qualifications.

During the month of March I had charge of some investiga-

1734 tion to determine the time it would take for water to flow through the drainage canal, the Desplaines River and the Mississippi River to St. Louis.

The work was first begun at Peoria. The date of that was on

1736 Saturday, March 14, 1903.

Total time as observed from Lockport, opposite the bear-trap dam to opposite the chain of rocks, St. Louis, of nine full days and three minutes, and, as I said before, including the forty minutes' cal-

culation, 934 hours and 26 minutes through the drainage canal
1742 or a time noticeably less than ten and one-half days from the south end of the Chicago River to opposite the waterworks intake at the chain of rocks.

Cross-Examination.

Q. Do you know, as a matter of fact, whether the river was high or low?

A. It was high.

Q. Now, what was the stage of the Illinois River from the time that the floats were placed in it until the end of the experiment?

A. In general the Illinois River was high.

1747 Q. Was it very high?

A. Yes, sir.

Q. The bottom lands and the overflowed land along the Illinois River was very extensive, was it not?

A. Yes, sir.

Q. The river was sometimes four or five miles wide in very high water?

A. It may be.

Q. From water line to water line?

A. Yes, sir.

Q. But at times during this experiment the river was out of its banks and overflowing the bottom lands?

A. In great many of them.

Q. Well, the ordinary banks of the river at all places were overflowed with water?

A. Yes, sir.

1748 Q. The water extending out into the bottoms?

A. Yes, sir.

Q. Is it not a fact as a general observation that the floats nearest the center of the channel traveled most rapidly?

A. Yes, sir.

Q. And the floats nearer the shore were much slower?

A. Yes, sir.

Q. So that the fact is that in the center of the channel the current of the river, wherever it may be, moves according to this
1752 observation much more rapidly than the water does on the side.

A. Yes, there is a very distinct difference.

Q. Then the total time of nine days and three minutes is the fastest time that these floats make down the Illinois River?

A. Yes, sir.

Q. So that, from your observations as determined, is the quickest time of the most swifly flowing water from Lockport to Grafton?

A. Under conditions existing at the times the observations were made, yes, sir.

Q. Now, is it not true that the current of the Illinois River at the time of these observations was very much swifter in the
1753 channel than at the ordinary stage of the river?

A. I suppose it is.

L. B. ENGLISH.

1846 List of typhoid deaths in cities in the Mississippi Valley:

GEO. CHANDLER WHIPPLE.

Direct Examination.

1903-4-5-6 Qualifications.

1912 The Organisms found in Lake Michigan.

1914 The examination of the water for diatoms.

1924 Synedra, pulchella, variety, sub pro longata.

Q. Now, what conclusion do you draw from that?

A. I should draw this conclusion, that the 16 synedra which were found in the intake of the St. Louis waterworks came, not from the Missouri shore, nor from the Mississippi River at a point above Grafton, but rather from the Illinois River at Grafton, and if we consider that there were 577 synedra in Lake Michigan, with only an average of 17 per cubic centimeter in all the tributaries of the Illinois River, I should conclude that the chances were that the 16 organisms found at the intake of the St. Louis waterworks, or most of them, came from Lake Michigan.

1926 Q. Now, with reference to some of these other diatoms, did you notice anything of consequence with reference to them?

A. That is considered tabellaira. There were 236 tabellaira per cubic centimeter on an average in the water of Lake Michigan. * * *

Q. Now, what conclusion would you draw from that?

A. This conclusion: That in all probability the tabellaira found in the settling basins of the St. Louis waterworks and at a point in the Mississippi River near the Illinois shore, came, not from the Missouri River or from the Mississippi River, at a point
1927 above Grafton, but from Lake Michigan by means of the Illinois River, and not from any of the tributaries of the Illinois.

Q. Would this enable you to distinguish which came from Lake

Michigan and which came from other sources when they were taken from the water at the intake?

A. Yes, sir.

Q. And you did so?

A. Yes, sir.

Q. To what did you attribute their origin, that is where they originally came from?

1930 A. So far as all my observations show, I should say that they came from Lake Michigan.

Q. I will ask you, Professor, whether you are able to form an opinion from your observations and the results thereof as depicted on these diagrams, as to the relative amount of water that enters the intake, as to the relative amount of water coming from the Illinois and Missouri Rivers. I will ask you first whether the relative amount of waters coming from these streams are capable of being determined from this data?

A. Yes, sir. I think that they are.

Q. Did you make calculations in that respect?

A. Yes, sir. I made calculations from the table of averages which has been submitted and I made these determinations

1937 from this table of averages.

Q. Are you for the present leaving out of consideration the turpidity of the water or is that entering into your calculation?

A. In this calculation I am considering only the average results of the melisira, the cyclotella, and the asterionella, and the stephanodiscus, which we found in the places mentioned.

Q. Now what were your conclusions?

A. I concluded that on an average 32 per cent. of the water which entered the intake of the St. Louis waterworks was considered Mississippi River water and that 68 per cent. of the water was Missouri River water.

Q. Is that result arrived at by calculation or by guess-work?

1938 A. By mathematical calculation.

CARL UNGER.

1955 Table of typhoid deaths and cases.

GEO. C. WHIPPLE,

1978 continued:

Q. Independent of the sanitary conditions, what are the general characteristic features of the Missouri River water and the Missis-

sippi River water at the mouth of the former or at the mouth of the Missouri?

A. Judge, from the samples of water which I have received from the Missouri at Bellefontaine, I will not say from Bellefontaine, but from the sections shown upon the chart which I have before me, from Section B and from Section M, in the Mississippi River, upon this chart, I should say that the water in the Missouri River is MUCH MORE MUDDY than the water in the Mississippi River—that is, that it contains a very much larger amount of suspended matter, and by referring to the analyses which I have made, I can show
1980 that by figures as well as by this general statement.

* * * * *

These figures bear out the general statement which I made that the water in the Missouri River is much more muddy and contains much more suspended matter than the water of the Mis-
1981 sissippi River.

Q. Assuming that the Mississippi River water above the mouth of the Missouri River contains certain forms of vegetable life which can be distinctly identified by well defined characteristics, and further assuming that the Missouri River water at that time contained no such species of vegetable life, and that these forms of life were present in water drawn through the intake tower at the chain of rocks, I will ask you to state what that shows as to the presence of Mississippi River water in the intake?

A. If I should find the organisms which you mentioned in the water of the Mississippi River above the mouth of the Missouri, and if at the same time these organisms were absent from the water of the Missouri River itself, and if at the same time these forms of life were present in the water drawn through the intake tower at the chain of rocks, it is my judgment that these organisms found at the intake tower of the St. Louis waterworks came from the water of the Mississippi River above the mouth of the Missouri River, and that they were borne thither by the water of the Mississippi River above the mouth of the Missouri.

Q. Assuming that at times the water of the Mississippi River above the Missouri contains very little mud, and that the water of the Missouri River at the same time is highly charged with mud, and further assuming that the water taken at the intake tower at the chain of rocks contains an amount of mud intermediate in quantity between those of the two rivers before they unite, state what in your opinion that shows with regard to the mixing of the waters
1982 of the two rivers.

A. Under the assumption just made, it would be my opinion that the water found at the intake tower at the St. Louis waterworks at the chain of rocks was not entirely water derived from the Missouri nor water derived from the Mississippi River above the mouth
1983 of the Missouri, but was a mixture of the two waters.

Q. Assuming that the table before you contains the correct number of total solids in the waters of the two rivers, state the degree of reliability of the percentage of the waters of the two rivers calculated from these total solids that would enter the intake at the chain of rocks.

A. It is my opinion that if the figures given in this table represent the total solids in the water of the Mississippi River at Hartford, and the water of the Missouri River at Bellefontaine, and the water of the intake of the St. Louis waterworks at the chain of rocks, if these figures are accurate representations of the total solids in the samples collected, and if the samples collected fairly represent the waters of the streams at the points named, then the calculations made by using these figures in obtaining the percentage of water of the Missouri River and of the Mississippi River above the mouth of the Missouri in the water of the intake of the St. Louis waterworks are
1985 reliable.

From these average figures I have calculated the percentage of the Illinois River water at the five points in the cross-section of the Missouri River water at Alton and obtained the following results:

At Station A, I obtained 7.8 per cent. of Illinois River water.
At Station B, I obtained 7.7 per cent.
At Station C, obtained 29.3 per cent.
At Station D, obtained 35.4 per cent.
1994 At Station 1, obtained 37.2 per cent.

Q. Mr. Whipple, assuming that at a certain time Lake Michigan water contained an organism called synedra pulchella sub pro longata variety, and that this plant is not contained at corresponding times in any of the branches tributary to the Illinois River, nor in the upper Mississippi River at Grafton, nor in the Missouri River water, and further assuming that this plant was found at a corresponding time in the water at the intake tower at St. Louis, what, in your opinion, does that show?

MR. TODD: I object to the question on the ground that the assumptions have not been established in the evidence, especially as to the Missouri River.

A. It would show that these synedra pulchella variety sub pro longata were not derived from the Missouri River water of the Mis-

sissippi River above Grafton, or from the tributaries of the Illinois River, but that it came from Lake Michigan and was borne thither by the water from Lake Michigan.

Q. Assuming that the Lake Michigan water contained at a certain time a certain organism known as tabellairia, and that this plant is not contained at a corresponding time in any of the branches tributary to the Illinois River, water, and further assuming that this plant was found at a corresponding time in the water coming from the settling basins of the St. Louis waterworks at the chain of rocks, what does this show?

A. It would show that the tabellairia found in the settling basins of the waterworks at the chain of rocks did not come from the water of the Missouri River nor from the water of the Mississippi River above Grafton, nor from the water of the tributaries of the Illinois River, but did come from the water of Lake Michigan and was borne to the settling basins above mentioned by the waters of Lake Michigan.

Q. What in your opinion is the duration of life of the germ of typhoid fever in natural water?

A. When the germs of typhoid fever are put into natural waters, they will continue to live for several months, though in gradually decreasing numbers.

Q. Assuming that the sewage and lake water passing from the Chicago River into the drainage canal reaches the Mississippi River at the chain of rocks in ten and one-half days, will the typhoid fever germs coming from the sewers in Chicago survive the passage through the Chicago River, the Chicago drainage canal, the Desplaines River and the Illinois River to St. Louis?

A. From what I know about the life of the typhoid fever bacilli in the water and from my knowledge of the conditions which exist between the Chicago drainage canal and the intake of the waterworks of St. Louis at the chain of rocks, it is my opinion that if typhoid fever germs exist in the sewage of Chicago, they will survive the passage down the Chicago drainage canal, and to the intake tower of the St. Louis waterworks at the chain of rocks under existing conditions.

Q. Now, then, from your personal observations to which you have just testified, and assuming that the sewage and lake water passing from the Chicago River into the drainage canal reaches the Mississippi at the chain of rocks, in ten and one-half days, will typhoid fever germs coming from the sewers in Chicago survive the passage through the Chicago drainage canal, the Desplaines River and the Illinois River to St. Louis?

A. It is my belief that they will.

Q. Assuming that at times of the flood conditions in the Illinois River the period of passage of Chicago sewage to the chain of rocks at St. Louis is eight days—is it or is it not true that that would enable a greater percentage of the typhoid fever germs to survive the passage to the chain of rocks at St. Louis?

A. Under the conditions assumed it is my judgment that a greater proportion of typhoid fever germs would reach the intake of St. Louis waterworks from the Chicago drainage canal when the time of transit was eight days than when the time of transit was

1998 ten and one-half days.

Q. From your general knowledge of typhoid fever epidemics, state whether there are cases on record where such epidemics have occurred, where the evidence shows the typhoid fever germs considered to have caused the epidemic remained in the water for at least ten and one-half days prior to the entrance of the water in the service pipe of the community where the epidemic prevailed?

MR. TODD: I object to the question on the ground that he has not shown that he has any knowledge on the subject of typhoid.

MR. JEFFRIES: State whether or not you have any such knowledge.

(Question withdrawn.)

Q. Go ahead and answer the question.

(Last question read.)

MR. JEFFRIES: Go ahead and state. I will state the question again. From your general knowledge of typhoid fever epidemics, state whether there are cases on record where such epidemics have occurred where the evidence shows that typhoid fever germs considered to have caused the epidemic remained in natural water for at least ten and one-half days prior to the entrance of the water in the service pipes of the community where the epidemic prevailed.

(Question objected to.)

A. I believe there are such cases on record.

Q. State the cases that are on record of this character.

A. The epidemic which occurred at Detroit, Michigan, and the epidemic which occurred at Lawrence, Massachusetts.

JUDGE SPRINGER: What year was that?

1999 A. I don't recollect the year.

Q. From your knowledge of existing conditions of the Chicago drainage canal, as you have just testified, and of the several connecting water courses between that canal and the intake tower of the St. Louis waterworks at the chain of rocks, is it or is it not your

opinion that there exists no work of artificial construction which continuously insures the prevention of typhoid fever germs which may enter the Chicago drainage canal, from reaching the intake of the St. Louis waterworks at the chain of rocks?

A. It is my opinion that no such work of artificial construc-
2000 tion exists as to bring about the results mentioned.

Q. Assuming that between January 17, 1900, and December 31, 1902, as compared with the period from 1895 to 1899, inclusive, there had been no increase on an average in the number of deaths from typhoid fever in those cities situated upon the Missouri River, upon the Mississippi River above Grafton, and upon the Illinois River and its branches, exclusive of the Chicago drainage canal, and further assuming that the typhoid fever death rate in the City of St. Louis had increased about 54 per cent. on an average during this period over the previous period mentioned, and further assuming that there was no substantial change in the manner of treatment of the water supply of St. Louis, and assuming further, that since January 17, 1900, a large part of the sewage of Chicago has been passed through the drainage canal and thence into the Desplaines River and into the intake, and assuming further that some of the water of the Mississippi River would contain a certain amount of Illinois River water at the intake of the waterworks at the chain of rocks, state what, if anything, in your opinion the Chicago water at the drainage canal had to do with the increased typhoid death rate in St. Louis.

A. Under the assumption which you have mentioned, and if the conditions named are those which obtain, it is my judgment that the sewage of Chicago was the most probable cause of the typhoid
2000-2001 fever in the City of St. Louis which you mentioned.

Q. From your knowledge of the existing conditions in the Chicago drainage canal, and of the several connecting water courses between that canal and the intake tower of the St. Louis waterworks at the chain of rocks, is it or is it not your opinion that there exists any reliable and efficient natural agencies which can continuously insure the prevention of typhoid fever germs which may enter the Chicago drainage canal from reaching the intake of the St. Louis water-works at the chain of rocks?

2002 A. It is my opinion that no such natural agencies exist.

Q. Assuming that 106 barrels, containing forty gallons each of the culture of bacillus prodigiosus, each cubic centimeter of the culture solution containing about 1,000 million prodigiosus germs, were emptied into the Chicago drainage canal at Lemont and further assuming that at the time of this experiment these germs were absent

Lake Michigan water, and Illinois River water and its tributaries, the Mississippi River at Grafton, and in the Missouri River water, nd assuming that soon afterwards some colonies of bacillus prodigio- s on several occasions were found in samples of water taken from e intake tower at the chain of rocks, what, in your opinion, does this ow?

A. Under the conditions mentioned in your question, it is my inion that the finding of colonies of bacillus prodigiosus at the in- ke of the waterworks at the chain of rocks, if they were found at ch a time after the introduction of the culture of prodigiosus into e Chicago drainage canal, at Lemont, as was consistent with the me required for water to pass from the one place to the other, and f these bacilli were absent during this period from the water of the issouri River or from the water of the Mississippi River, or from e water of the tributaries of the Illinois River, or from the water f Lake Michigan, it is my opinion that the origin of the bacilli found was the culture that was introduced into the Chicago drainage 002-2003 canal.

GEORGE C. WHIPPLE,

Continued:

Q. Mr. Whipple, assuming that since January 17, 1900, a larger amount of the sewage from Chicago has entered the Desplaines and Illinois Rivers via the Chicago drainage canal than was previously the case, and assuming that the water of the Illinois River containing such sewage enters the Mississippi River and passes to the intake of the St. Louis waterworks at the chain of rocks, what, in your opinion, is the relative safety of the St. Louis water supply at the chain of rocks in the Mississippi River before and after January 17, 1900, with reference to its use for drinking purposes?

A. Upon the assumption named in the question, it is my judgment that since January 17, 1900, the water at the intake of the St. Louis waterworks has been relatively less safe for drinking purposes than prior to that time. * * * It is my judgment that the most dangerous kind of pollution of such water supplies are the dejecta and urine of human beings, such as are commonly found in the 2008 sewage systems of cities and towns.

CROSS-EXAMINATION,

By General Hamlin.

"I stated that there were two micro-organisms, vegetable plants, if you choose, synedra and tabellairia, which were especially characteristic of Lake Michigan water, but not of the waters of the Missouri River or of the Mississippi River above Grafton, or the tributaries of the Illinois River."

Q. Right there, now, Mr. Whipple, do I understand you to mean that these two do not exist in the waters of the Mississippi River above Grafton—these micro-organisms?

A. No, sir.

Q. You do mean that?

A. No, sir; I don't mean that.

Q. Then, they might be found so far as you know, in the Mississippi River above the mouth of the Illinois?

A. They certainly might.

Q. And do you mean to say that they cannot be found or do not exist in the waters of the Missouri River?

A. No, sir.

Q. Do you mean to be understood as meaning that they do not exist nor cannot be found in the tributaries of the Illinois?

A. No, sir. * * * They are usually found in the waters of lakes, ponds or reservoirs. I do not know how many lakes are situated on the Illinois River between Lockport and Grafton, and have no personal knowledge on that point, and have no knowledge whether or not there are any lakes or ponds that connect with the
2019 Mississippi River above Grafton.

Q. If there were lakes on the Illinois River between Lockport and Grafton that connect with the Illinois River, you would expect to find these micro-organisms, wouldn't you?

A. They might be found there.

Q. Well, wouldn't it be reasonable to suppose that they would be found there?

A. At times, yes, sir.

Q. And the same is true of the Missouri River and of the Mississippi River, isn't it, under the same conditions?

2020 A. Yes, sir.

Q. Are dilution and sedimentation regarded by scientists and sanitarians as the two important elements in the purification of water?

2021 A. They are regarded as the two important elements.

Q. Well, if there had been determinations of solids at these points, wouldn't it have been a better or more correct test than to use the chlorine?

A. Yes, if there had been a greater difference between the total solids in the Illinois River at Grafton and the Mississippi River above Grafton, than was the case with the chlorines.

Q. You stated yesterday, I think, to Mr. Jeffries, that the best test—that is, the most reliable test—is the test made with the solids.

A. I consider it to be such for the particular case which is being discussed. I already laid that down as a universal proposition.

In the report of Jacob A. Harman, the total population of the Illinois River drainage basin in the year 1900 was 893,723.

In the same report the urban population for the same region for 1900 was 617,664.

I find from Harman's report that the area from the water-shed of the Desplaines River, the Kankakee River, the Fox River, the Vermillion River, the Mackinac River, the Spoon River, the Sangamon River, etc., that the sum of these drainage areas equals 27,914 square miles, and I have a memorandum made from the eleventh United States census which states that the drainage area of the Illinois River was 29,013 square miles, and another memorandum taken from the report of the chief of the weather bureau from 1896 to 1897, which states that the drainage area of the Illinois River was 29,150 miles.

Q. You have no means of telling with any degree of certainty the amount of sewage discharged into the Illinois River, exclusive of the Chicago River, the Illinois and Michigan canal and the drainage district, have you?

A. No, sir.

Q. WHEN YOU SPEAK, THEN, OF THE TYPHOID BACILLUS REACHING THE INTAKE AT THE CITY OF ST. LOUIS, IF SUCH A THING SHOULD OCCUR, YOU HAVE NO MEANS OF KNOWING OR SAYING WHETHER SUCH TYPHOID BACILLUS WOULD COME FROM, HAVE YOU?

A. I couldn't say definitely.

Q. You cannot say with any certainty, can you?

A. I cannot say certainly without comparing the population which drains into the Chicago drainage canal and thence into the—I will say the sewered population which drains into the Chicago drainage canal and thence into the Illinois River with the rest of the sewered

population on the water-shed of the Illinois River and its tributaries,
and the Mississippi River above the Illinois River and the
2036 Missouri River.

Q. Now, as such an expert, if typhoid fever germs were discharged into the Mississippi River at Alton, or the Missouri River at St. Charles on the Missouri River, wouldn't they more likely reach the intake than if discharged into the stream, say, 300 miles away, the stream that composed the Mississippi River before it reaches the intake?

A. That would depend upon a series of conditions, among which would be included the number, character of the typhoid bacilli, discharge, the distance of the point of discharge, from the intake of the St. Louis waterworks along the water courses, the manner in which the several streams mentioned become mixed before the water reaches the intake of the St. Louis waterworks and the character of the water into which the typhoid fever bacillus were discharged.

Q. Assuming the conditions of the various streams of water about which you have testified would a typhoid bacillus discharged into the water at Alton, or St. Charles, be more likely to reach the intake at St. Louis than it would if discharged into any one of those streams 350 miles away.

(Question was objected to.)

A. I have not testified to enough of the conditions men-
2037-2038 tioned to enable me to answer the question.

Q. Assuming the conditions of the various streams composing the Mississippi River at the intake at St. Louis, as you understand them, would a typhoid bacillus discharged into the Missouri River at St. Charles, Missouri, or at Alton on the Mississippi River, more likely reach the intake at St. Louis than a typhoid bacillus discharged into the water of any of these streams 350 miles away from the intake?

A. In so far as the question of distance alone is concerned a typhoid bacillus would reach the intake of the St. Louis waterworks from St. Charles, Missouri, or from Alton, Illinois, more easily than a typhoid bacillus of equal vitality introduced at a distance of 350 miles from the intake of the St. Louis waterworks, but whether or not a typhoid bacillus discharged at St. Charles or at Alton would actually reach the intake of the St. Louis waterworks more easily than a typhoid bacillus of similar vitality discharged at a distance of 350 miles from the intake, would depend, among other things, upon the degree of mixing of the waters into which the bacillus was discharged before it reached the intake of the St. Louis waterworks, and to some extent, perhaps, upon the character of the water into which the bacilli which

were introduced at a distance of 350 miles from the intake of the St. Louis waterworks were introduced; and it would depend still further upon the velocity of the streams into which the bacilli were
2038 discharged at the three points mentioned.

Q. If it depended on velocity, the one nearest the intake would reach the intake first, wouldn't it?

A. Provided the velocities of the streams were such that the one which was nearest the intake got the shortest time of transit.

Q. Now, so far as the vitality is concerned, do you want to be understood that a typhoid bacillus with equal vitality at Alton and starting on its journey to the intake with one of equal vitality 350 miles away, that one would be as liable to reach the intake as the other and still maintain their vitality?

A. If by vitality you mean the ability to resist external conditions, that would depend upon the relative character of the water into which the bacillus was introduced at Alton, and the water into which the bacillus was introduced at a distance of 350 miles, and the time required for the bacillus to travel from Alton to the intake of the waterworks, as compared with the time required for the bacillus to travel from a point 350 miles away to the intake of the
2041 waterworks.

The drainage area of the Missouri River was about 527,000 square miles, and the drainage area of the Mississippi River was about 143,512 square miles; the Illinois, 126,750, making a total for the three water-sheds of the three rivers mentioned, and excluding
2041 the canals named, of 699,525 square miles.

The aggregate urban population on the three water-sheds mentioned in the last question was in towns of over 4,000 inhabitants, according to the United States census of 1900, 2,694,738.

Q. How far, according to the authenticated cases of the contamination of water that has produced typhoid fever, has been the distance from the point or place where typhoid fever was contracted by water contamination?

A. To the best of my recollection, and in the absence of my notes, it is my opinion that this distance has been as great at times as fifty or sixty miles.

Q. Then it is true that the majority of cases that have been reported in this country and in Europe are less than thirty miles?

A. Yes, I should say that the majority of the well recognized epidemics caused by water-borne typhoid fever bacilli were due to infection of less than thirty miles distance.

Q. Suppose in 1902 that the number of reported cases of ty-

phoid fever in St. Louis was 1,112, and the number of deaths was 222, and that the same year at St. Charles, Missouri, a distance of thirty-five miles—St. Charles then having a population of 7,982—and the sewage of St. Charles, including that of two or more hospitals and the public schools, as well as the population of the city, and that for the year 1902 typhoid fever was epidemic in St. Charles, and assuming further that the sewage thus discharged from St. Charles was carried down from the Missouri River to the Mississippi River and from there to the intake of the St. Louis waterworks, traveling that distance in that way, to what, then, would you attribute the increase of typhoid fever cases and deaths in St. Louis for the year 1902?

(The witness, after making a great number of additional suppositions, concluded his answer with the statement that "the as-
sumption made is insufficient for me to answer the ques-
2047-2048 tion.")

(Then follows a long hypothetical question in regard to the deaths in St. Louis, and his answer thereto is very interest-
2049-2051 ing.)

CROSS-EXAMINATION.

By Mr. Todd.

I have no definite idea of the ratio of pollution of pure water to sewage because it would depend not alone upon the amount of pollu-
tion, but also upon the character of the water which was pol-
2051 luted.

I mean by character, the character as shown by those qualities which might be used in determining the possible pollution of the water. There are no qualities in the water which, taken alone, would enable me to determine the possible pollution of water, but among the qualities which I should naturally consider in forming an opinion, as to the possible pollution of the water, would be the amount of organic matter as shown by the amount of albuminoid ammonia, and the character of the organic matter with reference to the decomposition as shown by the free ammonia, the nitrites, the nitrates, the amount of chlorine in the water and the hardness of the water; the total solids, the suspended solids and the color of the water, meaning by that the organic matter in solution which exhibits itself as a vegetable stain, the number of bacteria in the water and the presence of certain particular species of bacteria in the water, such, for example, as the bacillus coli communis; also the possible presence of certain micro-organisms commonly associated with sewage pollution.

Q. Are those the qualities to which you refer in the former answer, in water, which would enable you to determine whether water is much polluted or not by sewage?

A. Yes, sir.

Q. In the absence of knowledge that sewage enters the waters, can the fact that the water is sewage polluted be ascertained from the different elements that you have enumerated here in your previous answer?

A. I believe that at times it can be and at other times it cannot be.

Q. What are the times that it can be and what are the times that it cannot be?

A. I believe that it can be when the amount of sewage pollution is considerable and that it cannot be when the amount of sew-
2053 age pollution is very slight.

Q. In other words, to see if I understand you, it would be a question of whether the water polluted the sewage or the sewage polluted the water under these conditions?

A. It would be. Just read the question again.

(Question re-read.)

A. It would be a case of comparing the water with the sewage.

Q. Under the state of things that you have enumerated in your previous answer, wouldn't it also involve a comparison of the sewage with the water?

A. We should compare the sewage with the water and the water with the sewage.

Q. Then what would be the character of the water necessary to enable you to ascertain when sewage empties into that water, whether it is sewage polluted or not?

A. The character of the water will have to be different from that of the sewage, but just how different I am unable to state, or I will say to what extent it is different I am unable to
2054 state.

Q. Assume that you determine the absence of all these qualities in water before the sewage enters into the water, what proportion, then, of the water, with the absence of these elements, and sewage would enable you to determine the presence of sewage in water of that character?

A. If you mean by that question the proportion of sewage in a water free from those qualities mentioned as shown by the amount of those qualities after mixture of the sewage with the water, I could not tell the proportion unless I knew the character of the sewage and

the changes which might have occurred between the time when the sewage was added to the water and the time when the analysis was made.

Q. Then, in order to ascertain the presence of the sewage in water of the character that we have been talking about, with these elements eliminated, is it necessary to make a chemical analysis of the sewage before it enters that water in order to ascertain the proportion of the sewage to the water into which it enters in order to ascertain its presence?

A. In order to ascertain the proportion of the particular sewage mentioned, it would be necessary to make some sort of an analysis.

Q. Then, in the absence of any analysis having been made of the sewage before it entered the water, is it possible to ascertain the presence of the sewage in the water intot which it empties?

A. It might be possible to ascertain its presence, but not its
2055 exact proportion.

Q. Are you able to state from your knowledge of the sewage of Chicago before it co-mingles with the waters of Lake Michigan, at what proportion of water to sewage you would be able to ascertain the presence of sewage in that water?

A. No, sir.

Q. Your experience as a scientist has not enabled you to make that kind of a determination, has it?

A. It has not enabled me to determine that point exactly.

Q. Then the line between much polluted water and slightly polluted water has never been scientifically defined, as to the ratio of sewage to water, or dilution, has it?

A. It is my opinion that it has not been truly defined, and that it cannot be truly defined. * * *

Q. If he (a scientist) didn't know the character of the water into which the sewage entered or the character of the sewage that entered the water, in fact didn't know that any sewage entered the water at all, what would have to be the results of the analyses in order to demonstrate the presence of sewage in the water?

A. I should be unable to state in definite terms.

Q. Don't you know?

2057 A. Not in definite terms, no, sir.

Q. What significance has the presence of albuminoid ammonia in water as to determining the presence of sewage or not?

A. It serves as a measure of the amount of undecomposed organic matter present, but, taken by itself, it cannot be used to determine the amount of sewage pollution present.

Q. The presence of sewage pollution was my question, not the amount.

A. That's what I meant.

Q. You said the amount.

2059 A. I meant the presence.

Q. What is albuminoid ammonia?

A. There is no such substance.

Q. There is no such substance as albuminoid ammonia?

A. No, sir.

Q. What did you mean by it, if no such substance exists?

A. It is simply a form of expression for describing the amount of organic matter present. It is a form of expression for the substance and is not the name of the substance itself, and albuminoid ammonia is not a name that attaches to any particular element

2069 known in chemistry.

Q. Isn't albuminoid ammonia a chemical element the same as nitrites and nitrates?

A. Not as we understand it in water analysis. * * *

Q. What does it (free ammonia) mean?

A. If the water is said to contain free ammonia, we mean that the water contains ammonium compounds which are such as, upon boiling the water, the ammonia will be driven off in such a way that its amount can be determined. * * *

Q. Is there any difference between the use of the term free ammonia to water in defining an element than in using the word "albuminoid ammonia" in defining an element?

A. Neither of them are the names of substances actually existing in the water, but rather they stand for substances existing in the water, * * * and are used synonymously with the substances themselves; practically so for practical purposes in water analyses.

Q. What are nitrites? Are they substances or the name for a substance?

A. It is both.

Q. What are nitrates?

2061 A. They are also a substance which may exist in water.

Q. From what source do you get what is known as free ammonia in water?

A. Sometimes from organic matter, from decomposition, and other times by the reduction of nitrites or nitrates. * * *

Q. Can you get free ammonia by the reduction of nitrites and nitrates?

A. You can get the nitrogen of the ammonia.

Q. Can you get free ammonia? Can you answer that question, Mr. Whipple?

A. Yes.

Q. What is your answer?

A. You can get the nitrogen free ammonia, as the expression is used, in water analysis.

Q. My question is, can you get free ammonia from nitrites and nitrates? Do you know?

A. You can if there are any compounds in the water which would unite with the free ammonia to form ammonia compounds.

Q. Is it not a fact that when you get nitrites, the process of purification is completed, and what is known as the nitrogen circle has been perfected?

A. If we start with organic matter as represented by albuminoid ammonia and if this decomposition progresses we may get all of the nitrogen compounds in the form of nitrates. * * * Albuminoid ammonia may be derived from either animal or vegetable matter.

Q. When you find the presence of albuminoid ammonia in water, does the science of chemistry enable you to ascertain whether that albuminoid ammonia comes from animal or from vege-
2062 table origin?

A. No, sir.

Q. That is a chemical impossibility, is it not?

A. With our present method of determination or analysis with the substances represented by the term of albuminoid ammonia, it may be derived from or may be either animal or vegetable matter.

Q. And is it not a fact, Mr. Whipple, that it is beyond the pale of chemical science to ascertain whether the presence of albuminoid ammonia in water is derived from animal or from vegetable origin?

A. FROM ANY METHOD OF CHEMICAL ANALYSIS WITH WHICH I AM FAMILIAR, IT IS IMPOSSIBLE TO TELL WHETHER THE SUBSTANCE REPRESENTED BY THE TERM ALBUMINOID AMMONIA IS DERIVED FROM ANIMAL OR VEGETABLE MATTER.

Q. Then, if that fact remains in doubt, the presence of free ammonia which is derived from albuminoid ammonia by the operation of the an-aerobic bacteria upon it is also in doubt, is it, as to its origin?

A. The origin of the free ammonia, which may be present, whether from vegetable or animal matter, cannot be definitely determined, although, if the amount of free ammonia is high, compared to the amount of albuminoid ammonia found, there is, to some extent,

more reason to expect that it came from animal matter, using the terms free ammonia and albuminoid ammonia as standing for the substances.

Q. Would that be a scientific fact—a scientific demonstration?

A. I shouldn't say that it rises to the dignity of a scientific demonstration.

Q. Anything that falls below the dignity of a scientific demonstration, you would characterize it how as a scientist?

A. I would use the term estimate.

Q. It is merely an estimate which doesn't arise to the dignity of a scientific demonstration, is it?

A. That is probably a fair statement.

Q. And it is as liable to be wrong as it is to be right, is it not?

A. No, sir, I would say it would be more likely to be right than it would be to be wrong, but I couldn't say how much more.

Q. Well, would it be sufficient for you as a scientist to put yourself on record as saying that you could tell by the quantity of free ammonia in the water whether it came from animal or vegetable origin?

2064 A. No, sir.

Q. Then if you found nitrates in the water analysis, these nitrates may come not only from animal and vegetable, but also from mineral origin?

A. They might.

Q. Then when they come from mineral, does that come from sewage of any kind?

A. Not unless the sewage contains minerals from which they came. * * *

Q. Well, if these nitrates should come from mineral origin, would you say that they came from mineral sewage or from mineral outside of sewage?

A. I couldn't say definitely without knowing whether any of the sewage entered the water, or whether the water in any way

2065 came into contact with minerals which would give up nitrates.

Q. Mr. Whipple, if nitrates are found in the chemical analyses of water, does their presence there indicate from what source they have their origin, whether vegetable, animal or mineral?

2065 A. No, sir; not simply because they are found there.

Q. Does the presence of albuminoid ammonia, free ammonia, nitrates and nitrites, of themselves, in large or small quantities, determine the presence of sewage pollution?

A. Not necessarily.

"The hardness of water is an attribute which is derived chiefly from mineral origin, and to some extent is derived from animal excreta, but to what extent I should not express that in definite terms, but I might say that that would be a smaller factor to be considered than most of the other elements which I mentioned. Of itself
2066 it would not decide sewage pollution."

Q. Now, from the table and analyses that you have before
2067 you (Complainant's Exhibit 1 for identification), are you able to tell whether that sample of water (on the first line of sheet numbered 5785) was sewage polluted or not, or whether these elements were derived from animal or from vegetable origin?

A. I am not able to tell either of these things from these figures as I find them right here, considering nothing else than these figures. * * * I should want to have more information, more practical information in regard to the source of this sample,
2068 and the place from which it was derived. I should like to know the character of the water-shed from which this water was derived with reference to the existing pollutions.

Q. Then, if you did not know the character of the water-shed you could draw no conclusion from that as to whether it was sewage polluted or not, could you?

A. I don't think I could from this particular sample. I think the analysis is of such a character that it would be difficult to tell from the analysis itself whether this water was sewage pol-
2069 luted.

Q. Do you consider the water of the Missouri above Kansas City a sewage polluted water?

A. In so far as the sewage of the cities dwelling upon the water-shed of the river above that point enters the river, I should consider it as a sewage polluted water.

Q. Suitable for drinking purposes?

A. That I am unable to state from the facts which I have at
2071 hand.

Q. Have you an opinion as to whether the water of the Missouri River at Fort Bellefontaine is sewage polluted or not?

A. In so far as the population of the water-shed on the Missouri River above that point is concerned, or in so far as the sewage of that population is concerned, I believe it to be a sewage polluted water to the extent mentioned.

Q. To what extent?

A. In so far as the amount of sewage from the population dwelling upon the water-shed enters the water of the Missouri River

and in so far as the ingredients of this sewage are not discharged or diluted or otherwise removed from the water of the river be-
2074 fore it reaches Bellefontaine.

Color of the water which shows itself of a brownish stain is due to vegetable matter in solution and does not indicate sewage pollution.

* * * * *

Q. You spoke of the presence of bacilli coli communis, what does that indicate—sewage origin?

A. I would not state definitely that it does indicate sewage origin. It is believed by many scientists to-day that this organism may be found in water where sewage pollution may be remote. This organism is a common inhabitant of the human intestine present in large numbers in ordinary sewage, and this organism is found so often and in such quantities in waters which are known to be sewage polluted and which is found so rarely or in such small quantities in waters which are presumably not polluted, that most bacteriologists are agreed that the test for the presence of this organism is a most important one to be considered in determining whether or not the water is sewage polluted. * * * I hold that if this organism is constantly present or is very often present in a water, and if this organism is present in such numbers that we can readily determine its presence by analyzing one cubic centimeter or less of the water, it is probable that this is an indication of contamination by fecal matter. I DO NOT BELIEVE THAT THE TEST IS AN ABSOLUTE TEST, BUT I CONSIDER IT A VALUABLE ONE TO BE
2075 INTERPRETED WITH THE REST OF THE ANALYSIS.

* * * *

It is my judgment that the presence of the fish, even though the bacilli coli communis might be found in their intestines, would not materially influence the interpretation to be made from the results of the coli test of water.

Q. Why?

A. Because it has been my experience that the intestines of fish do not ordinarily contain these bacilli. * * * I would disregard its presence in the intestines of the fish so far as any interpretation were made from the presence of the coli communis in
2076 the water.

"I don't know of any (micro-organisms) that absolutely demonstrates its (sewage) presence, but there are certain micro-organisms that are so often associated with sewage that in a general way they do serve as an indication of the presence of sewage, but I wish to be

understood as saying that they indicate it only in a very general way."

Q. Now, Mr. Whipple, we have gone through all the elements which you have indicated that the analysis would show, are there any of these elements, taken separately or combined, that demonstrate their origin to come from the fecal discharge of man, if found in water?

A. There are none of the elements which you have mentioned, taken singly, that would demonstrate that fact.

Q. Or taken collectively?

A. And even when taken collectively they are not always able to demonstrate their origin as coming from man, but taken collectively, and making comparisons with what we know of their character and amount of sewage, we are sometimes able to judge as to whether or not a water may be polluted with sewage which presumably contains the dejecta of man.

Q. Is that an assumption or a scientific demonstration?

A. I wouldn't consider it as a scientific demonstration, but I would regard it as more than an assumption. I would regard it as a fair estimate of the conditions.

Q. Does the words "fair estimate," in the sense you use
2078 them, rise to the dignity of a scientific demonstration?

A. No, sir; I wouldn't call it a straight scientific demonstration, but I would consider it what you may call a reasonably correct judgment.

Q. And that judgment which you define a reasonably correct judgment is liable to be mistaken, is it not?

A. Yes, like all human judgments.

Q. Is an estimate in the sense you use it a scientific demonstration of a fact in regard to stream pollution?

A. Perhaps in the straight sense in which you mean.

Q. I want to know what you mean, if you will excuse me for suggesting it, as you are testifying and I am merely asking.

A. Perhaps not in the straight possible sense, but I believe that what you may call a scientific estimate may often be considered as giving us reasonably correct results. * * * The accuracy of the judgment will depend upon the basis upon which that judgment is found, and upon the character of the person who makes that judgment, his experience of the subject upon which the judgment
2079 is made, and such general conditions as that.

Q. Then, when scientists get to that point where they cannot demonstrate by analysis they can merely approximate the truth by an opinion or an assumption, is that right?

A. No, sir, I don't think that is right. When they get to a point

where they cannot make an absolute demonstration, they combine the best available data which they can get and make the best scientific judgment which they can from this data. They do not abandon all data and simply make a guess.

Q. You wouldn't call that judgment scientific though, would you?

A. I would call it a judgment based on scientific facts. To
2080 that extent it would be a scientific judgment, perhaps.

Q. Do you know how long the bacillus of typhoid will live in sewage contaminated water running in a river.

A. I don't know definitely.

Q. Do you know of any scientist who knows or who has asserted it as a fact?

A. I don't know of any scientist who actually knows. I know the bacillus of typhoid fever will live in sewage polluted water, but scientists have made laboratory experiments to determine that fact and they have arrived at certain conclusions.

Q. Do you consider conditions in the laboratory where experiments have been made similar to conditions that exist in a running stream sewage polluted?

2081 A. No, sir, I do not.

I know of no experiments that have been made in the rivers themselves. I don't see how it is possible in the present stage of bacteriology for reliable experiments of that character to be
2083 made.

Q. Do they (typhoid bacilli) increase and multiply while in water?

A. I believe that the best scientific information which we have on that point leads us to suppose that after leaving the human
2085 system they do not ordinarily multiply in the water.

Q. Now, by the time that sewage of Chicago gets to Peoria, do you know whether that sewage would be purified or eliminated from the waters or not?

A. Under the conditions which exist it is my judgment that the proportions of the sewage of all parts of the sewage of the City of Chicago would not be eliminated by the time that it reached Peoria.

Q. What part would be—50 per cent., 75 per cent., or are you able to state?

2089 A. I am unable to state definitely.

Q. Upon what do you base that opinion?

A. Perhaps I can illustrate that better by example: If we take

chlorine, for instance, which is a constituent of sewage, that chlorine would not be affected by sedimentation, but practically only by dilution, and to that extent the sewage of Chicago would not be eliminated by the time it reached Peoria, but simply reduced in amount by the dilution it might receive. Under certain conditions I regard chlorine as an evidence of sewage pollution.

Q. Do you regard chlorine in the Missouri River as an evidence of sewage pollution?

A. From what I know of existing conditions on the water-shed of the Missouri River and from the fact that there are certain solid deposits—there are said to be certain solid deposits on that water-shed—and from analyses which I have seen showing the indication of such solid deposits, of the effect of such solid deposits on the water of the Kaw River, it is my opinion that the chlorine in the Missouri River in its low reaches cannot be used as an index of pollution, although part of it may be derived from sewage pollution, because the effect of the chlorine from the solid deposits would simply mask any chlorine from sewage pollution, and in that particular case the chlorine could not be used to determine whether or not the water was sewage pol-
2090 luted.

* * * * *

Q. Is it your opinion, and I believe you stated that the increase in typhoid in the City of St. Louis is due to the sewage from the drainage canal from 1900, 1901, and 1902?

A. I think that I stated that under certain conditions which were assumed the most probable cause of the increased typhoid in the City of St. Louis during that period was due to the sewage of Chicago, meaning by that, THAT WAS THE EASIEST EXPLANATION OF THE INCREASE UNDER THE CONDITIONS WHICH WERE ASSUMED.

Q. Does an easy explanation always explain, Mr. Whipple?
2091 A. It doesn't always explain.*

*A question involving the facts in regard to the increase of typhoid fever in St. Louis in November, 1899, met with an answer that the assumptions were not sufficient to enable him to make an opinion.

"In ascertaining or endeavoring to find out the cause of the increase which you assume to be considerable, and which I believe, if I remember correctly, was the case, I should wish to know, among other things, if any changes had occurred in the water supply system of the city compared with previous years, to naturally investigate questions concerning the milk and other foods, also the apparently high increase would hardly be due to such milk or food, though
2094 I do not say that it absolutely could not be.

Q. YOU CANNOT STATE AS AN ESTABLISHED

FACT THAT THE OPENING OF THE DRAINAGE CANAL AT LOCKPORT IS THE CAUSE OF THE INCREASE OF TYPHOID IN ST. LOUIS, CAN YOU?

A. I CANNOT STATE IT AS AN ESTABLISHED FACT, ABSOLUTELY AND CONCLUSIVELY PROVEN.

Q. Is chlorine in water injurious to health?

A. No, sir; not unless you would get an extensive quantity of it and it would probably be impossible to get enough to injure one, as I understand the question.

CROSS-EXAMINATION,

By Judge Johns.

Q. Have you traveled up the Illinois River at all?

A. No, sir.

Q. Did you make a physical examination—

A. No, sir; excepting that I have seen it—no, sir; using the words "Illinois River," I will say I have not.

Q. Have you traveled up the Mississippi River with a view of determining its physical surroundings and conditions?

A. No, sir.

Q. Nor up the Missouri River?

2099 A. No, sir.

Q. Is it a fact that if two chemists make an examination of water at the same points, taken at the same time, they will differ in their results?

A. That might happen.

Q. There is no such thing as a well defined and definite standard for the potability of water, considered independently of its physical history, is there?

A. I do not consider that there is, but I do not consider that the term potable has a well defined and definite meaning, and if that is the case we cannot have a definitely organized standard 2100 regarding it.

"I do not consider that there is a well defined standard regarding what I may term 'the safety of water' with respect to its use for drinking purposes, excepting that of the absence of substances which might render the water safe. * * * It is my opinion that it is a practically unknown subject as to whether or not the presence of micro-organisms would render a water which was once unsafe safer for use than if they were not present. It is my opinion that there may be perhaps some influence which certain micro-organisms exert

upon bacteria which might tend in that direction, but I do not
2101 believe that information of that character is very definite.

Synedra and tabellairia could exist in the lakes along the Illinois River. These organisms are well distributed geographically, and the State of Illinois is within their geographical distribu-
2104 tion.

Synedra, coming from a point 150 miles, and from another point sixty miles, to a given point, and as to which one would arrive at the given point alive, is a matter that cannot be answered, because of the lack of knowledge of their life history, and other as-
2107 sumptions.

Q. Suppose bacilli naturally inhabitants of running waters which are turbid to some extent, should be removed from their natural place of abode, developed by special culture, put in bottles of sterilized water, and hung out in the sun, would that be a fair means of determining how long they lived in their natural waters?

A. I don't think it would enable us to tell how long they would live in their natural waters; no, sir.

Q. Such an experiment would only prove how long they did live under the circumstances in which they were experimented upon?

A. Yes, just the results would be available in so far as—

Q. So that an experiment of that kind proves nothing as to the life of any particular bacillus in its natural situation?

A. It does not enable us to give a definite opinion as to that
2111-2112 point.

By the exposure of the bacillus prodigiosus under special culture to the sun for any number of hours, we could not determine how long it would live in its natural waters undisturbed, but balancing up the conditions of the laboratory experiment with conditions of nature it might guide us in our opinion as to how long it would live in nature, but it could not definitely determine that.

Q. The conditions of the laboratory experiments in which the bacillus, if produced by artificial culture and exposed to the sun in a bottle of water to which it is in nature totally unaccustomed, could not very well be balanced to the natural, could it?

A. It could not be balanced so as to obtain a definite result,
2112 no, sir.

Q. Do you mean to say, from the total solids and the percentage of total solids entering the intake upon the day upon which you made the calculations, that the percentage of actual water was the same, or do you simply mean to say that the percentage of water carried a certain percentage of the solids in solution?

A. Carried a certain percentage of the solids in solution, and to represent relatively the volumes of the water as far as the
2116 solids represented the samples.

CROSS-EXAMINATION.

By Judge Springer.

Q. In order to reach a correct conclusion, as to a sanitary condition of a given water, it would not be necessary to obtain the number of samples or to make a number of examinations of these samples, both bacterially and chemically?

A. The larger the number of samples, and the more complete the examination made, the more—the better judgment we could make of the sanitary condition of the water or the samples analyzed.

Q. Can microscopic examination of water be depended upon to determine the pathogenic qualities of drinking water?

A. No, sir.

Q. Are the common microscopic organisms found in water the cause of disease?

A. They are not so far as I know. * * *

Q. Where the chemical examination of water may determine the amount of organic matter contained in the sample, does it determine the nature of the water?

A. It does not definitely determine the nature of the organic matter in the water.

2121 Q. What would be the more delicate forms?

A. Well, some of the protozoa, such as dinyobryon, and some
2124 of the blue-green algae, as, for example, anabena.

Q. In your examination of the bottles from the rivers to which our attention has been called in this investigation, and Lake Michigan, you stated that there were two micro organisms which you discovered in Lake Michigan which you did not find in the waters of the Mississippi and Missouri Rivers. Do you mean to have us infer that this genera were not present in these waters?

A. In the first place, I did not make a statement exactly as you have told it. I think that I said that there were two organisms which I called synedra pulchella variety, sub pro longata and tabellairia, which were especially characteristic of those two waters, but I think I stated that only with regard to the synedra, pulchella variety, sub pro longata, that that organism was not found anywhere less than in the water of Lake Michigan or the waters with which Lake Michigan might have been afterwards mixed. * * *

Q. Are not the micro-organisms which you found in Lake Michigan found in all parts of the world, and under a great variety of climatic conditions?

2125 A. I believe they are, generally speaking.

Q. Might not an examination of a sample of water in the Missouri River or in the Mississippi River above Grafton, taken to show the presence of the two genera which you failed to find in the samples found in Lake Michigan?

A. They might. * * *

Q. How many of such samples did you receive?

A. I should have to look at that sheet in order to refresh my memory. (After referring to chart): I received five samples which I analyzed, but I might add that I received two broken bottles marked as having contained samples from the Missouri River. As the bottles were broken when I received them, of course they contained

2126 no water.

Ten samples were taken from Lake Michigan. The details are

2127 given on page 2127.

Q. If additional samples of water have been taken at other times during the year 1901 and examined microscopically to ascertain the presence of the micro-organisms to which you have referred, is it not probable that these other samples of water would have disclosed (taken at Bellefontaine or in the Mississippi River above Grafton) would have disclosed the presence of the two genera which you stated were not found at those places?

A. I can't say that it is probable that they would, but they certainly might have disclosed it.

Q. They migh thave done so?

2128 A. Might have done so, yes, sir.

Q. In your examination day before yesterday, I believe it was you?

A. I believe it was.

Q. You cited two instances in which typhoid fever germs had existed for ten days previous to their introduction to the water supply from which an epidemic had originated. Will you please state the distances which were traveled by the germs before they reached the water supplies which they entered?

A. I cannot tell you exactly, but in the case of Lawrence, which I mentioned, it was supposed that the typhoid bacilli traveled from Lowell down the Merrimac River, thence into the water supply system and through the reservoir into the—perhaps I had better say through the reservoir into the water supply system, a distance which

was somewhere near twenty miles, I cannot say exactly. I have frequently covered the distance. I am speaking quite from recollection.

Q. And that other case?

A. The other case was that of Detroit, where, if my recollection serves me, the distance traveled was some fifty or sixty miles, again speaking from recollection.

2128-2129 Q. Then we may reasonably conclude that the pathogenic germs, such as typhoid germs, for instance, do not multiply in water?

A. I think it is the consensus of opinion that the pathogenic germs like typhoid fever, as I say, do not multiply.

2130 Q. Have scientists or authors upon the subject ascertained by any experiments to-day the probable duration of pathogenic germs, such as typhoid fever, in running water?

A. I don't think they have, excepting by means of laboratory experiments, which naturally cannot be made under the same conditions as actually exist in running waters. * * *

Q. Would laboratory experiments be more favorable to their existence or less favorable to their existence than the natural conditions?

A. It is my opinion, speaking generally, that the laboratory
2131 experiments would be less favorable than the natural conditions.

Q. In unsterilized water and the presence of the ordinary river bacilli—water bacilli—will they disappear in proportion of these numbers or increase in proportion of these numbers?

A. I don't think that that can be stated, because the identification of the presence of typhoid bacilli in the presence of common water bacilli is an extremely difficult thing, and it is in most instances impossible to determine the presence of a typhoid fever bacillus in the presence of a lot of common water bacilli. I know that to be
2132 true from experiments which I have made. * * *

In an experiment made at Munich, upon which was predicated a question as to the experiments of typhoid germs, this answer was elicited:

A. I should say from these results that if the common water bacillus increased as you mentioned, it was no wonder that the men didn't find typhoid bacilli in the samples at the end of seven, nine or ten days. In the presence of such numbers of common water bacilli, I don't believe that it is a bacteriological possibility to demon-
2133 strate the presence of typhoid fever bacilli.

DEATHS FROM TYPHOID FEVER—U. S. CENSUS, 1890.

Cities.	Population.	Deaths for 10,000.
St. Paul	133,000	6.9
Minneapolis	164,000	5.7
Memphis	64,000	5.1
Omaha	140,000	4.5
Kansas City	132,000	4.
St. Louis	451,000	3.2
New Orleans	242,000	1.9

2143 These estimates were made for 1890.

Q. Do not scientists universally recognize as a fact that the greatest pollution in streams of water is at times when the flood is the greatest or the flow of the water is the greatest?

A. No, sir, I should not think that was universally recog-
2146 nized as a fact.

Q. Then, if I understand you correctly, you are of the opinion that it cannot be determined with certainty whether there are typhoid germs in natural running water?

A. I believe it to be a fair statement to say that in ordinary natural running water there is no practical method by which the presence of the typhoid fever bacillus can be determined. I do not think that it is absolutely impossible to do so, but there is no practical everyday method for doing so.

Q. If it is impracticable to ascertain the absence of pathogenic germs in the natural water, it would be equally impracticable to ascertain their presence in the same water?

A. I consider the two propositions as practically one. The germ may be there, and you might fail to find it, and it might not be there when you failed to find it. It does not depend upon whether you find it or not, but whether you can ascertain its presence by any chemical or bacterial means or any other means. I stated that I do not consider that there is a practical method by which the presence or the absence of the typhoid fever bacillus can be ascertained in natural waters by chemical or bacterial means.

2148 RE-DIRECT EXAMINATION.

By General Crow.

If we consider that the liquid which leaves the drainage canal at Lockport is polluted sewage, and to be flowing at the rate of 300,000 cubic feet per minute, and if to that is added 40,000 cubic feet

per minute of diluting water, the sum of these two amounts would be 340,000 cubic feet per minute, and of this sum about 88 per cent. would be the diluted sewage.

2149 In regard to the assumption of Asiatic cholera in Chicago, the witness answered:

A. Under the assumption made, I believe it is possible that these germs might find their way to the intake of the St. Louis waterworks.

Q. Why?

A. Because I do not believe that there are any existing artificial or natural agencies which would at all times insure the pre-

2150 vention of these germs reaching the intake.

The banks of the Mississippi River from Grafton to the mouth of the Missouri River is practically straight. The channel changes from side to side during the reach of the river, and a greater mixing occurs than if the channel was straight.

2151 Q. Assuming that the mineral stream flow of the Mississippi River at the chain of rocks is at times as low as 40,000 cubic feet per second, and assuming that the Chicago drainage canal is increased in the future from 5,000 cubic feet per second to 10,000 cubic feet per second, state what, in your opinion, would be the effect of such an increase upon the amount of infectious material which may reach the chain of rocks at the intake tower of the St. Louis waterworks?

A. It is my opinion that under the increased condition of flow there would be a material increase in the liability of infectious material to reach the intake tower of the St. Louis waterworks from the Chicago drainage canal.

Chemical contents of three samples of water submitted to the witness for an opinion as to how they rank in regard to dilu-

2153 tion of sewage.

Sample No. 1 was assumed to be taken from 2421 Dearborn Street, Chicago.

Q. If water of the character of sample No. 1, and that is known to have produced typhoid in the City of Chicago, and samples 2 and 3 are mixtures of this water, and the diluted sewage of Chicago, what do you say as to the probability, considering dilution alone, of these latter samples producing typhoid fever if used for domestic and drinking purposes?

A. Why, if water of the character of sample No. 1 has been the cause of typhoid fever, and if this sample be compared with samples Nos. 2 and 3, which, according to the analyses and the previous

assumptions, indicate a less degree of dilution with the sewage, it would be my opinion that there would be more chance of samples Nos. 2 and 3 causing typhoid fever than sample No. 1, so far as dilution is concerned.

2152-3-4-5 The water of the Mississippi River below the mouth of the Illinois and above St. Louis waterworks is less valuable for drinking purposes now than before the emptying of the drainage canal waters mixed with the waters of the Chicago River into the Illinois River.

2155-2166 RE-CROSS EXAMINATION,

By Judge Johns.

I have never been on the Mississippi River between the chain of rocks and Grafton. I derived my knowledge of the banks and reaches and curves between the chain of rocks and Grafton from several maps, among them the Government charts and charts

2157 of the Mississippi River Commission.

I don't know whether the charts were made within the last five years or the last ten years, but think they were made along in the '80's.

Q. Do you know whether these charts represent the condition of the banks and the curves of the Mississippi River in January, 1900?

A. Not exactly, but I believe that, speaking generally, they might represent them. I have no doubt that there have been

2158 slight changes.

My knowledge (of the probability of the waters of the Illinois River reaching the intake of the St. Louis waterworks) is not derived from a personal inspection of the river in that reach, but from various maps and charts, among them the Government charts, which were made on dates which I do not just recollect, but not very far, and I believe from the dates you mentioned.

Q. Assuming that the volume of the Illinois River at Peoria before the opening of the drainage canal given you, namely, 40,000 feet per minute, is the volume at the lowest known stage of the river, at any time within the last twenty-five years, would you think that assumption fair, upon which to make a calculation of the percentage of dilution?

A. It would be fair with reference to that particular time.

Q. Assuming that at all times since that data was given the volume of the Illinois River had been greater and that it has at

Peoria at some times been as much as 2,000,000 feet per second, would you be able to form any opinion as to the percentage of dilution at any other time than the exceptional time given you in this suppositious question?

A. Why, no, I could form simply an opinion of the dilution at the time when the figures were given.

2159 Q. Then the greater the dilution the less the chance of harm?

A. That is certainly true as far as dilution goes.

Q. Well, if the waters of the Illinois River to which are added 300,000 feet of water from Lake Michigan, certainly reach, in your opinion, the intake of St. Louis, why wouldn't the waters of the Illinois, to which were added 40,000 feet of water, as certainly reach the intake at St. Louis?

A. I think that so far as dilution alone is concerned, they might as certainly reach so far as dilution is concerned.

Q. But if for fifteen years prior to 1900, substantially the same amount of sewage discharged into the Illinois River from Chicago, diluted with 40,000 feet of water, as is discharged since 1900, diluted with 300,000 cubic feet of water, then the danger of disease in St. Louis from the sewage of Chicago, diluted with 40,000 feet of water, would be more than seven times as great as if diluted by 300,000 feet of water, would it not?

A. In so far as dilution itself is concerned, that would practically be the case. So far as dilution is concerned, dilution

2162 is a good thing.

Q. When you say that the pollution in the Illinois River is sometimes appreciable at the intake and at the chain of rocks, to what extent do you mean appreciable?

A. I mean that if the Illinois River is polluted that that pollution may reach the intake at the chain of rocks, but I cannot state the extent to which it would reach the chain of rocks or when it would.

Q. Can you say whether it would at all times?

A. I cannot say whether it would at all times. I cannot definitely designate the season.

Q. Could you tell or do you know whether the pollution in the Illinois River was appreciable at the intake of the St. Louis waterworks in the fall of 1902?

A. I couldn't say definitely.

Q. Do you mean by appreciable simply capable of being perceived by scientific examination?

A. No, sir, I mean appreciable from a practical standpoint—

that it may have an effect upon the health of the people who drink the water.

Q. Do you mean to say that it does, as a matter of fact, have an effect on the health of the people?

A. I cannot say absolutely that it does, but I believe that possibility certainly exists.

Q. It is a possibility that it might?

A. I believe that it is.

2164 * * * * *

Q. Do you believe that the waters of the Missouri River have an appreciable effect upon the character of the waters at the St. Louis intake?

A. I cannot say absolutely that they do, but I believe that
2165 they may.

If there were typhoid germs reaching the intake on a certain day from the Missouri River, and if there were others reaching the intake from the Mississippi River and others reach it at the same time from the Illinois River, and if these germs caused typhoid fever in the City of St. Louis, I couldn't say exactly which one of the three or whether any of them caused the typhoid fever, and I couldn't tell the relative number of cases which each one caused without knowing more about the number of germs that came from each one.

2165 RE-CROSS EXAMINATION,

By Mr. Todd.

Q. Now, in regard to samples known as 1, 2 and 3, that you have testified about, did these samples indicate sewage pollution?

A. I couldn't say definitely from these samples without re-
2173 gard to anything else.

Q. Is there anything in either one of these samples which would indicate that if a person took into his system water similar—chemically similar—to either one of these samples, that he would contract typhoid fever?

A. No, sir.

Q. Do you know how long the germ of Asiatic cholera would live in running water?

2175 A. I don't know definitely, no, sir.

Q. What are the conditions of the water to-day as differing from the water prior to 1900 at the St. Louis intake?

A. As I understand it——

Q. From your actual knowledge then, independent of public bulletins?

A. As I understand it, there is a greater possibility to-day of the water supply of the City of St. Louis at the intake being polluted than there was before January 17, 1900, by reason of the discharge of the sewage of Chicago through the Chicago drainage canal.

Q. Has that probability been scientifically demonstrated?

A. I believe so, within the bounds of scientific judgment. It has not been chemically demonstrated.

Q. Has it been chemically demonstrated?

A. I have no information that leads me to believe that it has been chemically demonstrated, excepting that I understand that certain results of the analyses in general show slight increases in the organic matter, etc., indicating of itself, but not proved.

Q. Does this indication rise to the dignity of a proof?

A. No, sir, I do not consider that they do.

Q. Has the demonstration scientifically been made that the waters that enter the intake tower to-day are more injurious to public health than they were prior to 1900?

A. I don't believe it has been chemically or scientifically proved, but I believe that scientific judgment leads us to believe that such is the case.

Q. When scientific demonstration fails to establish a fact, then the so-called scientific judgment does not differ from the judgment of a man who is not scientifically advised drawing his inference from the same conclusion?

A. Where an absolute scientific demonstration is impossible the next best thing to my mind is a scentific judgment.

Q. Well, can a judgment be scientific when the facts upon which that judgment is predicated are incapable of scientific demonstration?

2180 A. No, sir.

RE-CROSS EXAMINATION.

By Judge Springer.

Q. Does the effect of sunlight upon these Asiatic germs tend to reduce their virulence and longevity in a very marked manner?

A. I should say, speaking in general, that sunlight would tend to produce longevity, but I cannot say quite as much as to the virulence, but it is possible that it might act in the same way with viru-

lence also as a rule. Speaking in general terms, sunlight is inimical to bacterial life.

2182 If it could be proven to me that such germs (Asiatic cholera) would not live in natural waters, under conditions existing, my conclusion might be changed, but just as in the case of typhoid fever. I am not sure at all that the conditions existing in a laboratory experiment would be comparable to those which would exist in

2182 running streams.

Q. In so far, then, as you can duplicate any one of these in a laboratory experiment—duplicate the conditions which exist in a natural water—in so far are your conclusions of value?

A. Yes, sir. Of course, we must also duplicate the conditions in regard to the organisms themselves used in experiments and those which were introduced in the water.

2183 Q. And that, therefore, the further you depart in your laboratory experiments from the conditions which prevail in the natural water, the further removed are your experiments from any particular utility?

2183 A. Yes, sir.

WILLIAM THOMPSON SEDGWICK.

2184 Direct Examination.

He is familiar, generally speaking, with the three watersheds

2190 above the St. Louis intake.

He differentiates between pollution and infection.

2190 Q. Professor, I will ask you to state whether or not dilution will destroy or eliminate infectious pollution or matter in water?

2191 A. No, sir. Mere dilution, I understand.

Q. Now, professor, on the basis of dilution alone, do you consider that the sewage from the Chicago Sanitary District as it reaches the Illinois River above Peoria, is at all times rendered safe and pure for domestic purposes?

A. No, sir.

Q. Will running water purify itself so as to be free from pathogenic bacteria that may have been placed therein?

A. In trying to answer the question specifically and closely, * * * I should have to say that running water under some conditions might conceivably, very largely and possibly altogether purify itself from infectious germs, but these conditions would have to be very unusual, and so unusual as to be practically theoretical, or vir-

tually theoretical. It was formerly believed by experts that running water readily purifies itself. That belief has been altogether abandoned. * * *

(Examples of mistakes made in Pittsburg, Niagara Falls, Buffalo, Cleveland, Detroit, Chicago, Duluth, which take their water supply subject to exposed contamination by sewage, are given.)

There is at times, in certain streams especially, a large measure of self-purification. The subject is a complex and difficult one, and the tendency of opinion, the growth of opinion, as to increase are distrusted in the efficiency—the efficacy of self-purification of

2191-92 water or sewage.

Q. State whether or not the sewage from a district as large as the Sanitary District of Chicago would affect the value for drinking purposes of a stream as large as the drainage canal and as large as the drainage canal and the Desplaines River and the Illinois River combined, and if so in what manner?

A. Yes, sir, the mere introduction of sewage into a stream at once creates suspicion as to the—at once throws suspicion upon the character of that stream, and unless it can be shown that that sewage has been effectually removed by purification, the value of that stream is distinctly lowered.

2193-4 Q. State your opinion as an expert on water supplies as to whether or not the waters of the Mississippi River west of the center of the main channel of said river below the mouth of the Illinois River and down to the intake tower of the St. Louis waterworks at the chain of rocks are less valuable for drinking purposes and more liable to carry water-borne diseases, such as typhoid fever and cholera, now than they were before the sewage from the Sanitary District of Chicago was run into the drainage canal and through it into the Illinois River.

2194 A. I consider it decidedly less valuable.

Q. Relative to the quantity of water in the Illinois River, do you know what proportion the added volume from the drainage canal would bear to the waters of the Illinois?

A. At the period of lowest flow, it might perhaps be as low as five or six. With the ordinary flow, of course, it might be less than that. I have only general knowledge of the hydraulics of the river.

Q. State whether or not an increase in the speed of the current in the Illinois River, by reason of the added volume of the water in the drainage canal, would affect the amount of sedimentation that might otherwise occur in the Illinois River, and if it does affect it, how and in what manner?

A. The addition of such a volume of liquid as passes through the drainage canal must materially, must often materially quicken the flow of the Illinois River. It must therefore hinder effective sedimentation, and thus, by shortening the time required for infectious germs to pass through the river, and by interfering with their detention, aggregate the danger of their arrival at the mouth of the river. I should like to say right here, that the time allowed in all these matters is very important, so that any quickening of the flow is a grave consideration. It is not so much distance as time that is the basis of self-purification of sediments.

Q. What effect, if any, would the increase in speed of the current in the Illinois River have upon the time within which sewage from Joliet, Peoria and other towns on the Illinois River might be removed into the waters of the Mississippi (if the same are so removed) as compared with the conditions that existed and the time it might have taken before the added volume of water from the drainage canal was poured into the waters of the Illinois?

A. It would shorten the time, because by increasing the flow, by quickening the flow, sewage or infectious pollution from Peoria and the lower points might arrive more quickly at the mouth of the Illinois and mingle with the waters of the Mississippi.

Q. If water is made more clean and less turbid than it was before by an added volume of water being placed therein, will such bacteria as typhoid have more or less tendency to go down to the bottom of the stream than they had prior to the water being rendered less turbid?

A. The clearer the water, the other things being equal, the clearer the water, the slower the rate of sedimentation. The more turbid the water the more rapid and the more effective the sedimentation, so that the condition of clear water to turbid water, as a rule, tends to postpone and delay sedimentation.

Q. If an increased volume of water in the Illinois, by the addition of the waters of the drainage canal, would make an increased speed in the current of the Illinois River, would that increase in said current have any effect in increasing or diminishing the typhoid and liability to typhoid and other water-borne diseases on the part of the inhabitants of the State of Missouri using the waters of the Mississippi River for drinking purposes below the mouth of the Illinois River?

A. I believe that it would have an effect and that it would
2196 increase the typhoid.

Q. Professor, are settling basins recognized at the present

time and have they been recognized at any time as an efficient and adequate means for the purification of sewage to be discharged into a drinking water stream?

A. No, sir. * * *

Q. What, in your judgment, becomes of the deposit matter in the beds of a running stream?

A. The deposit matters or the matters deposited in the bed of a running stream may lie there for some time or they may be swept out by an increase in the rate of flow in the stream. If they lie there for some time they may be more or less modified by chemical and bacterial action. If they are returned to the stream by an increase in its velocity they may be redeposited at lower points or borne on into some other body of water.

Q. What do you say as to the longevity of the germ of typhoid fever as a general proposition, in connection with sewage polluted water?

A. Here, also, our ideas are undergoing some change of late years. My ideas have undergone some change. Broadly speaking, the tendency has been to come to the belief or has been to show or to indicate a greater and greater longevity. Laboratory experiments have sometimes indicated a short and sometimes a longer longevity. Practical experience has tended to make us believe in a greater longevity than that formerly entertained, and having reference to the conditions in the stream, the various conditions in streams, MY BELIEF IS THAT IN A SEWAGE POLLUTED STREAM THE TYPHOID GERMS MIGHT LIVE IN GRADUALLY DIMINISHING NUMBERS FOR WEEKS OR MONTHS OR EVEN YEARS.

2197 Q. Assuming that the number of bacilli coli communis in the waters of the Illinois River at Grafton are at intervals no greater than the number contained in it before the opening of the drainage canal, do you consider for that reason that the water is at all times no more dangerous than formerly?

A. I do not. I consider that even if the number of coli bacilli as shown by occasional tests is no higher to-day or were no higher to-day than before the opening of the drainage canal, the mere fact of the addition of a vast population contributing sewage to the Illinois River constitutes and must always constitute an added menace to the health of persons using the water of the Illinois River at its mouth or below, and I may add that I have this opinion, or I will say for the reason, that bacilli examinations obviously cannot be made at every moment, or I will say at all times or all seasons or hours of

the day, and are at best not absolute guides as to the sanitary conditions of the water. There might be times and seasons when materials would flow by, escaping analysis, and pass on to do harm to the people below.

2197-98 I do not consider that typhoid fever germs coming from Chicago and deposited in Lake Peoria would be destroyed at the end of a month.

Q. Professor, assuming that typhoid fever germs coming from Chicago sewage are deposited in large numbers in the lakes and slack water portions of the Illinois River above Peoria, do you or do you not consider that flood conditions, such as would scour the deposits from the bed of streams, would cause the water leaving Lake Peoria to contain at times more infectious and dangerous pollution than are at present in the diluted sewage entering the Desplaines River at the beartrap dam at the foot of the drainage canal?

A. I think at times it might.

Q. Why?

A. Because, if accumulations of typhoid germs were formed in the lakes or slack water basins of the river, these might, especially in the case of a large amount of typhoid fever in Chicago, result in the storage there of a vast number of germs and the sudden flood might sweep out these accumulations and actually bring it about that sometimes more typhoid fever germs should be flowing in that stream than in the drainage canal.

2198-99 Q. Has the removal of deposits of sewage matter from the bed of streams resulted in causing typhoid epidemics?

A. I know of one excellent instance in a stream, and I think there have been some in lakes. Some cases of that sort in lakes or sluggish bodies of water. The best example, undoubtedly, that we have of such an effect in a stream, and it happens to be one that was combined with the slack water lake, so that we have the double demonstration in one case, is the well-known instance of typhoid fever in Detroit, resulting from the dredging of the Black River at Port Huron, which caused the carriage of detached sediment down St. Clair River through the St. Clair Lake and into the intake of the Detroit waterworks. I think that was in 1892, if I remember right. That is probably the most striking case we have on record. It was very thoroughly investigated and I am familiar with the data upon which the conclusions were based, and in my opinion it is a well established case, and it is the best that I know of.

Q. Now, assuming that the only pollution of the Illinois River was that contributed to by the Chicago Sanitary District, and having

in mind the large amount of typhoid fever existing in said district, do you or do you not consider the effects of the time interval dilution and sedimentation occurring between Chicago and Grafton, would be the City of St. Louis, and if so, during what period and with what result?

A. Emphatically not, for the reason that such processes of self-purification, including sedimentation and dilution, as would take place in the Illinois River and above to Chicago, would be, in my judgment, inadequate to insure at all times and seasons a complete removal of infectious matter.

Q. Have you had any personal experience which would lead you to believe that infected water coming from the Illinois River and entering the Mississippi might become mixed with the latter in such a way as to menace the health of the inhabitants of the Missouri shore of the Mississippi River waters for drinking purposes at points below on the Missouri shore?

A. I think that I have a very instructive piece of personal experience bearing upon that question.

(Then follows a citation of the Lowell epidemic caused from infection coming from a small stream entering the Merrimac three and a half miles above the intake.)

(Note: The two conditions at St. Louis and Lowell are by no means comparable.)

2200 Q. Professor, have you made any study of the typhoid fever statistics of the City of St. Louis, and if so during what period and with what results?

A. Yes, sir, I have made a rather careful study of the typhoid statistics of the City of St. Louis, and with this general result: During a period of fifteen years prior to January 1, 1900, the typhoid fever death rate in St. Louis has not in general been above that of some cities provided with water supplies considered pure and of good repute. During the period following the removal of the intake from the lower point to the chain of rocks, the typhoid fever death rate of St. Louis was rather remarkably good, by which I mean that it was lower than it had been and lower, for example, than the death rate of the City of Boston, for that period. Beginning with the 1st of January, 1900, there has been a marked annual increase in the typhoid fever death rate of the City of St. Louis, so that it has during that period not only been higher than during the previous period of five years, but also higher than at any time in its own history since 1885, and very much higher than the death rate in the City of Boston, with which previously it compared very favorably. If I may give

figures, I may say that the increase in typhoid fever deaths in the City of St. Louis since January 1, 1900, as compared with the preceding fifteen years, and excepting one year in 1892, when there was a great epidemic in St. Louis, an epidemic which was thoroughly investigated by Doctor Ravold, has been about 26 per cent., while the increase since January 1, 1900, in the annual mortality from typhoid fever as compared with the preceding five years, I think it was, at any rate as compared with the period between the removal of

2202 the intake to the chain of rocks, has been 73 per cent.

Q. Now, assuming that the only pollution upon the watershed of the Mississippi and its tributaries above the intake of the St. Louis waterworks was that derived from the Sanitary District of Chicago, and, having in mind the large amount of typhoid fever in Chicago, do you or do you not believe that infection and dangerous pollution might under existing conditions find its way into the water supply of the City of St. Louis?

2203 A. Yes, sir, I believe that it might.

Q. Assuming that there was no typhoid fever pollution of the waters upon the watershed of the Mississippi River or its tributaries above the intake of the St. Louis waterworks, other than that derived from the Sanitary District of Chicago, do you, or do you not believe that typhoid fever germs from said district are liable to find their way into the water supply of the City of St. Louis through the intake tower at the chain of rocks?

A. I believe that they are liable to find their way into the intake for the reason that typhoid fever, having been frequently very abundant in the City of Chicago, I MUST START WITH THE ASSUMPTION, that a very large number of typhoid germs find their way into the sewage of the city, pass through the sewers and on into the drainage canal, and, subject to local conditions may in diminishing numbers pass out of the Illinois River, mingle with the waters of the Mississippi, pass over to the other side and find their way to the intake at the chain of rocks.

2204 In regard to Ravold's prodigious experiment, the witness answers as follows:

"This interesting and valuable experiment, as I regard it, seems to me to show that typhoid fever germs might pass from the drainage canal through the Illinois River and the Desplaines River, and be carried alive to the intake of the waterworks at the chain of rocks, and there enter the water supply of the city, very likely producing typhoid fever at St. Louis."

2204 Q. Assuming that an epidemic of Asiatic cholera should break out in the City of Chicago, is it possible that the germs of that

disease might find their way into the intake tower of the St. Louis waterworks at the chain of rocks, from the City of Chicago?

A. I consider it possible that it might.

2205 Epidemics at Plymouth, Penn.

2205 Lowell.

2206 Newbury Port.

Lowell to Lawrence, about nine miles. Newbury Port to

2207 Lowell about twenty-five miles.

The Rivers Pollution Commission of Great Britain, in a report published by them in 1874, stated that there is no river in the United Kingdom long enough to purify itself from any sewage admitted to it, even at its source. That stands as one of the axioms of sanitary science to-day. This Rivers Pollution Commission, in 1874, I think it was, made that statement that there is no river in the United Kingdom, I think they said, long enough to purify itself of any sewage introduced into it, introduced at its source, and of course some of the rivers of the United Kingdom are very long.

2207 Windsor epidemic.

Typhoid conditions in Pittsburg, being due to infection coming from points as far away as Oil City, 113 miles.

2209 Ithaca epidemic.

2210 Hamburg epidemic.

I reported at Pittsburg, the distance of 100 miles, or even more remote points, infection coming from Oil City, 113 miles, or even more remote points, may produe typhoid fever. You have got to eliminate all the idea of distances from these figures and bring in the question of time largely.

2211 Q. Now, professor, considering your personal knowledge as an expert, of typhoid fever conditions in the Sanitary District of Chicago, and existing conditions in said district, as to sewers and the outfall thereof, and the amount of sewage and all the existing conditions of the Desplaines, Illinois, Mississippi and Missouri Rivers, and all conditions existing in the watersheds of said streams and the tributaries thereof, and the existing conditions as to the water supply of the City of St. Louis, and the general sanitary conditions existing in the City of St. Louis, would you, or would you not, beyond a reasonable doubt, attribute the principal portion of the increase of typhoid fever in St. Louis (assuming that there has been an increase in St. Louis since the opening of the drainage canal) to the infected sewage of the Sanitary District of Chicago?

A. After a careful consideration of the subject, I can say that in my opinion, beyond a reasonable doubt, the principal portions of the

increase of typhoid fever in St. Louis since January 1, 1900, or the principal annual increase since January 1, 1900, has been due to the pollution of the water supply of St. Louis by the sewage of the Sanitary District of Chicago.

Q. I will ask you to state, professor, if you did not say this morning in answer to one of my questions that from '95 to 1897 the typhoid rate was substantially normal in the City of St. Louis, comparing favorably with similar cities of like situations and of similar size, as to typhoid rate only?

A. From 1895 to '99, both inclusive, during these five years, yes. That was what I did say, although I should like to add that the word "normal" must be taken in a general rather than an advanced sanitary sense, for I believe that both Boston and St. Louis are capable of further improvements in these directions, and both
2214 are higher than New York and London.

Q. I will ask you to state, if you know, professor, how the typhoid rate compares in St. Louis city from 1895 to 1899, inclusive, with the rate from typhoid fever in Lowell after the introduction of the ground filter water supply, and in Lawrence after the introduction of the first-class filtration plant?

A. In 1895 to 1899 it compared favorably with the typhoid death rate of these cities.

Q. Have you any experience, professor, in investigating typhoid epidemics caused by seriously infected water in running streams that would cause you to believe any running stream can absolutely be relied upon at all times to remove disease-bearing germs, such as the typhoid bacillus?

A. No, sir, not if the pollution was at all serious or extensive.

(Note. Conditions at New Orleans, according to Weston's testimony, is ample contradiction for this position.)

Q. Professor, do you consider that the Illinois River water, containing the mixed sewage and canal water from the Chicago Drainage District, since the opening of the drainage canal, has rendered less safe and wholesome now than before the opening of the canal, for drinking purposes, on the part of the inhabitants of Missouri, the waters of the Mississippi River below the mouth of the Illinois River?

A. Yes. Now, in the first place, we have got to consider the matter of dilution. * * * At the same time it must be borne in mind that the water which is thus used for purposes of dilution is not itself the unpolluted water of Lake Michigan. It is drawn chiefly from the mouth of the Chicago River and vicinity, and Lake Michigan water in that vicinity, and at that mouth has long been known to

be infected more or less. The problem then resolves itself into this in part: Does the dilution of a presumably—of an often infected sewage—by a presumably often infected water contribute to the pollution of the Illinois River? But that is not all. The Chicago River was formerly a sluggish stream; to-day it is much less so, and these infectious materials which were formerly put into the Chicago River are to-day carried with comparative sluggishness down the drainage and into the Desplaines and Illinois Rivers. We have further this to consider, whether sewage carried quickly and in considerable volumes into the Illinois River does not render that river safer than before. My belief is that it is at least very doubtful whether the pouring of the sewage of Chicago into the Illinois River does at any time improve that river. Looking at it still more closely, and considering the larger amount of sewage now delivered, the opportunities for demonstration, the susceptibility of the Illinois River to freshets, large and small, and in view of the changed condition brought about by the introduction of this fresher sewage with a larger volume of water, I am inclined to believe that; and further, in view of the frequent extensive pollution of the sewage of Chicago by the infection of typhoid fever, I should say, I am inclined to believe, that the pouring of the sewage diluted as described into the Illinois River has not at any time improved it from a sanitary point of view, from the point of view of the health of the people who may use that water on the Missouri shore. I may say that undoubtedly at times it may have improved its appearance and may seem to have improved its quality, but, taking it through the year at all times—at all seasons—I am inclined to doubt exceedingly such improvements, any such improvements, at any time.

Q. Now, professor, I will get you to state whether or not, in your opinion, the liability to contract typhoid fever or other water-borne diseases on the part of the inhabitants of Missouri, using the Mississippi River water for drinking purposes below the mouth of the Illinois River, by reason of the sewage from the drainage canal infecting the water of the Illinois River, is constant, immediate and continuous under all existing conditions upon the Mississippi, the Desplaines, the Illinois and the Missouri Rivers, and the tributaries of said streams, and all existing conditions upon the watershed of said rivers and the tributaries thereof, and the drainage canal of the Sanitary District of Chicago?

A. I believe that the danger is practically constant, by which I mean that it can never be known at what moment infectious material may arrive from the sewers of Chicago. I do not suppose that such

material is arriving every minute or every hour, but I believe that the danger is constant, because we may never know when it may come. I believe that it is important in the sense that it is urgent and serious and I believe that it is impending from the fact that it is, as it were, hanging over the citizens of Missouri on the shore of the Mississippi all the time. I cannot help looking at the thing in this way: It is as if there were now located on the watershed of the Mississippi since the opening of the drainage canal a big additional city, a city notorious for the typhoid death rates or for the typhoid epidemics, I would say, and—yes, for its high death rate, too, from typhoid fever; and as if the placing of that city virtually upon the Mississippi watershed had introduced a new element into the life and welfare of the people on the river below. It is no trifling matter to take on a city of that size and add its sewage to an already sewage polluted stream. The danger line may by that addition be reached sooner, must in the nature of things be reached sooner by those who use the water, and it is for that reason that I do regard the danger as impending, immediate and aggravated as well as continued.

2218 Dams, undoubtedly, so far as they produce slack water and quiescence favor purification and the disappearance of diseased germs for the time being, but if the sediment of sludge is allowed to remain in the streams and not removed artificially or taken out or put off out of a position of danger, the chances are good and experience shows that in freshets it may be returned to the stream again because a part of it traveled with it and produced trouble below. * * * But it is a general principle that dams are useful. They are helps, but they are not sufficient to rely upon for purification, * * * and the only way they could be made efficient would be to have them made high enough to hold the water back and then carefully clean out the stuff and get rid of it, but even that would not do in case of water supplies, because of the very act of stirring up things, and you may get something from this as you did in the case of Detroit, in the epidemic which occurred there. The only safeguard is to keep the germs quiet in the sediment at the bottom so long that they shall have entirely died out. WE HARDLY EVER KNOW WHEN THAT IS. It is a very weak reed to lean on.

2219 My opinion is that the real growth in the Chicago Sanitary District is likely to exist and the total growth is likely greatly to surpass that upon the other places mentioned. I should expect it to be at least ten times as great. I will add to this answer, basing an opinion upon pages 119 and 121 OF THE ILLINOIS STATE BOARD OF HEALTH REPORTS FOR 1901, SANITARY DIS-

TRICT INVESTIGATIONS OF THE ILLINOIS RIVER AND TRIBUTARIES.

THE MERE PRESENCE OF POLLUTION—I MEAN BY THAT UNINFECTED SEWAGE—THAT IS, SUPPOSE CHICAGO HAD REDUCED HER TYPHOID RATE, SHE WOULD STILL POUR HER SEWAGE DOWN THE VALLEY, AND THAT SEWAGE, BY MERELY FAVORING THE LONGEVITY OR GROWTH OF GERMS WHICH GET IN FROM PEORIA OR ANYWHERES ELSE WOULD BE AN ADDED MENACE TO CITIES WITH WATER SUPPLIES, EVEN IF SHE DID NOT SEND TYPHOID FEVER GERMS DOWN. SEND-

2223 ING THE FILTH ALONE DOWN IS SERIOUS.

Q. Do you consider that the Illinois River water polluted and infected by the sewage from the Chicago Sanitary District since the opening of the drainage canal has rendered less safe the water supply of the City of St. Louis as drawn at the intake tower of the chain of rocks, and on what do you base your opinion?

A. I do consider it less safe, for the reason that I believe that the germs of typhoid fever may and do find their way through the intake of the chain of rocks to the water supply of the City of

2224 St. Louis.

Q. Assuming that the population of the Sanitary District of Chicago is increased to 5,000,000 of people, and that the flow through the drainage canal reaches 1,000,000 cubic feet per minute, what, in your opinion, would be the effect on the water of the Illinois River at its mouth, as compared with the water at that point as found during the past three years?

A. I believe that the water would be less pure, less wholesome, more infectious, and less suitable for drinking purposes, for the reason already given.

2224 Q. Assuming that the Chicago sewage from 1,500,000 people living in the Sanitary District and City of Chicago should be discharged into the Chicago drainage canal and carried through the canal into the Desplaines River, and thence into the Illinois River, Chicago being situated 357 miles from the St. Louis intake, and assuming that a typhoid epidemic of extraordinary proportions should become prevalent among the residents of the Sanitary District of Chicago at a time when the sewage from said district is being so discharged into the canal, what immediate and impending danger would exist and what effect would it have on the people of St. Louis and those people living on the Missouri side of the Mississippi River be-

low Grafton, who use the water of the Mississippi River for drinking purposes?

A. I believe that an epidemic of the kind described under the circumstances mentioned would, under the existing conditions, would be likely to produce an epidemic of large proportions among those so using the water.

Q. Now, professor, assuming the same conditions as in the last question, you have answered, and assume that, instead of an extraordinary typhoid fever epidemic prevailing in the Sanitary District of Chicago a cholera epidemic should prevail in the Sanitary District of Chicago, would the danger be imminent, impending and immediate to the people of Missouri below Grafton who use the waters of the Mississippi River for drinking purposes as far down as the chain of rocks?

A. I think it would, sir, for the simple reason that they could never be sure under existing conditions that some of the germs of that disease might not find their way into the water supplies

2225-26 from the sewage of Chicago.

(Question in regard to prophecy of the future.)

2226 Q. Now, professor, I will get you to state if you have any knowledge on the subject, from which you can give an opinion, as to whether or not the stream flow in this country will increase?

A. I have only a very general knowledge, but a very definite impression, and that is, following the results of experience, that we may expect that stream flows in general will not increase, but rather decrease as time goes on.

2227 Q. I will ask you this question, referring now to the question asked you on pages 17 and 18, and your answers thereto in your testimony taken yesterday afternoon, do you say now that the waters of the Mississippi are rendered less safe by reason of the water of the Illinois, of the Chicago canal emptying into it now than it was before the opening of said canal from the standpoint of the health of the persons on the Missouri shore on the Mississippi River below the mouth of the Illinois who may use or wish to use the waters of the Mississippi for drinking purposes?

A. Yes, sir, I should say that, in my opinion, it is decidedly less safe in spite of the fact that at times, as I have said, it may look better or seem better, and THE WHOLE BURDEN, I THINK, OF MY TESTIMONY WOULD BE TO STATE WHAT I BELIEVE TO BE TRUE, THAT THE QUICKENING OF A STREAM BY THE ADDITION OF A VOLUME OF OTHER WATER, ESPECIALLY UNDER CONDITIONS SUCH AS PREVAIL ON

THE ILLINOIS, IS A VERY SERIOUS MENACE TO THE PEOPLE IN THE REGIONS BELOW WHO USE THAT WATER. It is my opinion that in spite of the addition of the so-called pure lake water, in spite of greater dilution resulting from that, the water of the Mississippi River is constantly and beyond all reasonable doubt rendered more dangerous to health and to the citizens who use it because of that addition, and under all the circumstances
2230 which exist on the Illinois and Mississippi Rivers.
2231 Plymouth epidemic described in full.
2234 Chathaham, England, epidemic, in 1879.

Q. Professor, will you state in general terms, if you can, the relative efficiency of urban and rural population in the pollution and infection of running streams?

A. As a general proposition, the urban population is very much more dangerous—very much more efficient in the pollution of water than the rural population. It would probably be fair to say, to put it in figures, that the urban is at least ten times as dangerous,
2235 etc.

The drainage canal has added about 63 per cent. of the entire
2235 urban population to the watershed of the Illinois above the St. Louis intake.

The urban population on the Missouri River, 1,090,832; the
2236 Mississippi River, 12,219,645; the Illinois, exclusive of Chicago, 385,305.

Q. Do you know of any instance where settling basins holding suspected water for longer periods than this one at Lawrence have failed to protect the people using such water from typhoid fever, and if so, what are they?

A. There are well-known cases: Covington, Kentucky, and New Albany, Indiana, deserve mention. At Covington, Kentucky, the water of the Oklahoma River, more or less polluted on the stream above, is kept at times as long as thirty-two days, and yet Covington suffers severely from typhoid fever, apparently due from infected water. At New Albany, Indiana, on the same stream, the storage was about a month in the sedimentation basin, as in the case of Covington, but typhoid fever was high in New Albany, showing that the storage for a period even as long as a month cannot be depended upon to entirely remove the typhoid germs.

(Hypothetical question assuming the population and typhoid fever death rates in cities on the Missouri, Mississippi and Illi-
2239-2249 nois Rivers, inclusive.)

Occasionally, of course, a rural contamination may produce an

epidemic of typhoid fever, but such cases are infrequent and exceptional.

2251 Conduit question taking water of Lake Michigan and empty-
2251 ing into the Mississippi.

Q. Professor, will you state whether or not it is within the bounds of human possibility for any competent expert to say that in a period of low water in the Missouri River, such as is likely to occur at next Christmas time, a thaw on the Illinois watershed might not endanger the lives of the people using the waters of the Mississippi below the mouth of the Illinois on the Missouri shore, and at the City of St. Louis, by sending to them in that water the unpurified sewage of the Sanitary District of Chicago?

A. I don't believe that it is.

Q. Why?

A. Because, in my opinion, no competent expert either can or will say that any means exists at present by which such unpurified sewage can be warded off from the people of the Missouri shore and the citizens of St. Louis under these conditions.

2253 CROSS-EXAMINATION,

By General Hamlin.

2254 I should not recommend storage for St. Louis probably. That
2255 would have to have filtration.

Infection exists in the Mississippi, Illinois and Missouri Rivers.

2255 Q. But if the cities or towns below St. Louis on the Missouri side of the Mississippi River should take their water supply from the Mississippi River, they would be affected by the sewage of St. Louis, would they not?

A. If they took it unpurified, yes. I have studied in a general way the amount of sewage discharged into the Missouri River by considering the number and position of the cities above. * * *

Well, there is a large amount of sewage discharged into the
2257 Missouri and Mississippi Rivers.

Q. Then, according to your statement, in regard to this conduit, I will ask you this: Is it not your opinion as an expert that if you were to eliminate all the sewage from Chicago and take the Illinois with the Sanitary District out and its tributaries, and the Mississippi and its tributaries, and the Missouri, and combine these waters as they are combined above St. Louis, that you would have a badly polluted stream?

A. I should say unhesitatingly that the water is and would be, under such circumstances, a polluted water.

Q. And that the chances are that it would be dangerous to the people of the City of St. Louis and the towns below?

A. Certainly.

Q. And you believe that the best process of making this water potable here would be by filtration?

2257-2258 A. That is my judgment at the present moment, yes, sir.

Q. Well, then, so far as the purification of the water of St. Louis is concerned at present, and rendering it fit for domestic use here for drinking purposes, the expense of doing that would be the same whether the sewage of the Sanitary District was in it or not, wouldn't it?

A. The probable cost of doing it at present, owing to the conditions of the various rivers and at Chicago, would, I suppose, not be materially affected by the addition of the sewage of Chicago to the Mississippi River, as these rivers are and as that sewage is to-day.

CROSS-EXAMINATION,

By Judge Johns.

2258 I consider chemical examination of water as of importance in determining its condition for drinking under some circumstances, but not under all. I cannot determine the source of pollution by chemical examination. If the water is grossly polluted no great skill is required, if it is only slightly polluted, it might require a very high skill. Chemical analyses might determine the pollution of the Missouri River at times, and at times it might not.

The same thing is true of the Mississippi.

2258-2259 From bacterial examinations sometimes I can and sometimes I cannot determine its pollution.

Q. Could you determine from the joint consideration of the chemical analyses and the bacterial examinations of the waters of the Missouri, as shown in evidence here, whether such waters were polluted?

A. A joint examination would be preferable to the individual and separate examinations, but I should have to make the same answer. Sometimes I could and sometimes I could not.

Q. Then the chemical analysis and bacterial examination of the waters of the Missouri and Mississippi Rivers are not of themselves sufficient to determine the qualities of the water at all times for drinking purposes?

A. I should not consider them as competent at all times.

2260-61 The reaches of the river, a sluggish current, dams which retard the flow of the current, small lakes, overflowed bottom lands would contribute to the purification of a river.

2262 Q. Are you familiar with the general physical characteristics of the Illinois River?

A. I am from studying the maps and talking with men who have been up there.

Q. Not from any personal examination?

A. No, sir.

2262-63 It is this: That as far as possible all sewage should be kept out of drinking water, but I should be unwilling to take the ground that one microbe in the Mississippi or one spoonful of sewage in the Mississippi River at Minneapolis would make it impracticable for drinking purposes or unfit for drinking purposes at New Orleans. There are degrees of danger undoubtedly, but I don't feel able to define these degrees.

Q. Do you think that one gallon of sewage at Alton would pollute the waters of the Mississippi River at the intake tower so as to make them unsafe for drinking?

A. It might if it was typhoid infected.

Q. It might?

A. It might. I don't say that it would. It might.

Q. Do you think that one gallon of sewage at St. Charles put into the Missouri River and infected with typhoid germs would render the water at St. Louis unsafe for drinking purposes?

A. It might.

Q. Would you, as a general proposition, knowing that one gallon of sewage from St. Charles, infected with typhoid germs, had been put into the Missouri River, pronounce the water of the Missouri at the intake tower unsuitable for drinking purposes or unsafe?

A. Do you mean without purification? Oh, at the intake tower. Yes, I should not want to drink it and I should not recommend it to others to drink it if I could help it.

Q. Well, then, you would consider it unsafe?

A. I should consider it unsafe, yes, sir, as a general proposition, provided, of course, that I didn't know when that gallon was coming along. * * *

2264 A gallon of sewage, typhoid infected, in the Missouri River at St. Charles, I would consider unsafe for drinking purposes, as a general proposition. If put in at Kansas City I should not want to drink the water at that time when it was expected here, but I should

not be willing as a sanitarian to say that this was unsafe for drinking.

Q. Taking as your knowledge of the Missouri River, whatever it may be, and assuming that a gallon of sewage was put in that river, at Omaha, Nebraska, when the river was in its ordinary stage, and that the water in which the sewage was injected, typhoid infected sewage, arrived at the St. Louis intake, would you consider that water unsafe for drinking purposes?

A. I should like to look up the flow of the Missouri, which I do not recall now.

(Witness refers to papers.)

Am I obliged to answer that question?

Q. Yes, that is what you are here for.

A. I think I should consider that unsafe.

2266 Q. If in the year 1901 there were thirteen deaths from typhoid fever at Lincoln, Nebraska, fifty-eight in Kansas City, six in Omaha, twelve in St. Joseph and five in St. Charles, and a typhoid bacillus in each of these cases went by some means into waters of the Missouri River and some of them arrived at the intake in St. Louis, to which one of the six towns would you prefer to

2266 ascribe the bacillus arriving at the intake.*

A. I think they would be more likely to come from Kansas City.

Q. Why?

A. Because that would mean 580 cases in Kansas City and fifty cases in St. Charles, assuming a mortality of 10 per cent., and a likelihood of one getting into the intake at the chain of rocks would, I believe, be greater, all things considered, from 580 cases at that distance than from fifty cases at the other distance, or from those other numbers at their respective distances. IT IS A MATTER,

2268-2269 HOWEVER, ALMOST ENTIRELY OF GUESSWORK.

Q. Are you extremely uncertain as to whether the bacilli in the supposed case of Kansas City would arrive at the intake at all.

* * *

A. Kansas City—I think, I am extremely uncertain. I could not say positively that they would arrive, any of them.

Q. Could you say positively that none would arrive?

A. No, sir; I could not.

Q. Then you don't know whether they would or not?

A. No, I do not.

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*After a long discussion, the witness made this answer:

Q. Have you an opinion as to whether they would or not?

A. Yes, sir; I have.

Q. What is your opinion?

2270 A. I believe they would.

Q. How far is the longest distance, either in reported cases or in your own personal cases, or in your own personal experience, in which it is either known or supposed that typhoid bacilli have been transported by running waters and caused infection in some water supply?

A. Known or supposed—I think the greatest distance known that I now recall is that of the DETROIT EPIDEMIC, in which it was WELL ESTABLISHED—apparently well established that the infection was conveyed for about fifty-seven miles. The assumed and supposed distances, however, are very much more than that. For example, at Pittsburg, I myself supposed and assumed that typhoid fever germs might have come, as I said in my report, from Oil City, which was 113 miles, or even, as I remarked, from points much

2270 more remote. * * *

Q. Do you place any limit upon the distance a typhoid bacillus may travel in water and live and at the end of the journey be virulent?

2270 A. Not if the rate of travel is fast enough.

Q. You would not consider it possible that in the waters of Stony Brook or of Merrimac River or the reservoirs or wells or whatever they have at Lowell and Lawrence, there might have been injected typhoid bacilli by some malicious person?

A. Yes, it is possible.

Q. Then, if it is possible, the Lowell and Lawrence cases do not afford an accurate knowledge of the life history of bacilli, do they?

A. The Lawrence end would—no, but assuming that he did the same thing at Lawrence—no, sir; that would not, under

2273 those circumstances. * * *

Q. Well, then, you may just add any explanation to it that you wish.

A. I simply wish to make it perfectly clear that a malicious infection of the Lowell reservoir would not have invalidated my conclusion in regard to the Lawrence epidemic.

From Lawrence to Lowell is nine miles along the Merrimac River, and is thickly populated.

Q. Now, is it within the limit of probability that persons living

near the Merrimac River between Lowell and Lawrence might have had typhoid fever?

2274 A. Yes, sir.

Q. Were there no cases absolutely between the two towns near or on the banks of the Merrimac River?

A. I don't know.

Q. Is it possible that there might have been?

A. It is.

I examined the facts about the Lowell case about the first of January, when the disease was subsiding after the greatest

2275 degree of mortality.

Q. Then your information upon the subject was what lawyers call hearsay?

A. I don't know what lawyers may call it. It is the usual

2276 method of investigation in such cases.

I should say that he draws his conclusions from facts that he himself ascertains to be true to the best of his knowledge and

2277 belief, etc.

(Then follows the facts upon which he bases his opinion as to the Lowell and Lawrence epidemics, which is entirely hear-

2278 say and not competent evidence.)

Q. When you made an examination of the water supply at Pittsburg, did you go to Oil City?

A. No, sir. Yes, I did, but not further than to pass through.

Q. * * * Had there been previous to that a very great increase of typhoid in Oil City?

A. I don't remember.

Q. Do you know whether previous to that, and during the continuance of high rate of typhoid fever in Pittsburg, there was an excess of typhoid fever in Oil City?

2281 A. I cannot remember. * * *

Q. And without knowing whether there was typhoid fever in any one of these towns or an excessive rate of typhoid fever in any one of these towns, you ascribe the typhoid fever in Pittsburg to the infection of the Allegheny River above it?

A. I do not remember whether there was now, above or not, whether I base my conclusion upon that partly or not, but in any case, even supposing that there had been an excess up there, I should have come to the same conclusion before they were pouring regularly a certain amount of sewage into the stream.

Q. Then all that is necessary to make the waters of a running

stream unsafe as to typhoid fever is the fact that the sewage of populous places above is poured into the river?

A. Broadly speaking, yes.

Q. Without regard to the fact as to whether there is or has been typhoid fever in any of the populous places above where the sewage was poured into the river?

A. Yes, in taking this fact as an ordinary proposition and taking the question as a broad one, we may always assume that sooner or later there will be in the sewage of a populous city or town
2282 germs of typhoid fever.

DETROIT EPIDEMIC.

Q. Then they took the most easily ascertained and most prominent possible cause and ascribed to it and it alone the entire increase in sickness?

2284 A. I presume they did. That would be good sense.

A person in San Francisco, whose hands were infected by typhoid germs, might arrive in St. Louis and spread the disease there. Or if a person in San Francisco, packing goods and having typhoid infection on his hands, might communicate the same to the people in St. Louis or New York or London or St. Petersburg or Moscow or

Cartoon. The germs might live for a trip around the world of
2290-2291 sixty days, and the same is true of Asiatic cholera.

Q. Now, how did you arrive at that calculation and conclusion? I want to know the process by which you arrived at your conclusion of 73 per cent.

A. Certainly. I shall be very glad to explain that. I arrived at it in this way: IN THE ANNUAL REPORTS OF THE BOARD OF HEALTH OF THIS CITY WILL BE FOUND A TABLE GIVING THE TOTAL NUMBER OF DEATHS FOR THE NUMBER OF YEARS INDICATED, EXCEPTING ONE OR TWO WHICH ARE NOT YET IN THE RECORD, AND ALSO GIVING THE NUMBER OF TYPHOID FEVER DEATHS IN ANOTHER COLUMN, AS HERE FOR INSTANCE. (Referring to Board of Health reports.) The total annual mortality shown in one column and the total annual number of typhoid fever deaths in another column. If now, we figure the percentage which the typhoid fever deaths were of the total number of deaths, we obtain what is known as the
2294 percentage mortality of typhoid fever for each year.

* * * * *

This, however, is not absolutely exact, because the reports of physicians cannot be absolutely relied upon and the recording of the

deaths cannot be absolutely relied upon. It is a choice between two methods, and on the whole I prefer this one and have usually
2295 employed it.

Q. I want to know what you mean by reasonable doubt?

A. I mean by that an assurance of accuracy such as will persuade me of the truth.

Q. Did you ever know of a case or cases of typhoid fever which were certainly traceable to typhoid bacilli which had existed for any length of time in the sediment of a running stream?

A. I mentioned in my direct evidence the well-known epidemic in Zurich, Switzerland, which was reported by those who investigated it as clearly traced to the stirring of the sediment near a broken intake pipe, and I also mentioned, further, the Detroit case, which, to the best of my judgment and belief, was conclusively traced to the stirring of sediment in the Black River, near the St. Clair
2309 River.

Q. Is there any positive knowledge, as distinguished from theory or deduction, as to the existence of typhoid germs in the sediment of running streams?

A. Well, sir, I don't know how any branch of knowledge more positive than rigid deductions and I should say that the deductions drawn from the epidemics like that of Detroit and at Zurich are just as positive knowledge as we ever get in our ordinary scientific work in sanitary science and that they were not dependent upon theory.

Q. Do you know of a single instance in which the bacteria of typhoid fever have been found—discovered and identified in the sediment of running streams?
2312 A. I do not recall any such case.

Q. Do you now assert that a typhoid bacillus turned into the Illinois River from the drainage canal, having its derivation in Chicago, does live in a journey down the Illinois River and the Mississippi to the intake tower at St. Louis?

A. I am ready to assert my conviction, my positive conviction, that typhoid bacilli may and do live to make that journey.

Q. Based on what evidence?

A. Based on a whole chain of evidence which I have in my possession regarding the sanitary history of Chicago, the character of the water used to dilute the sewage of the City of Chicago, the character of the Illinois River, especially as to being subject to floods, and the character of the Mississippi River, into which the Illinois empties, and with which, in my opinion, the Illinois freely mixes, so that

such germs may be carried alive and virulent from the people of Chicago to the intake tower of the St. Louis waterworks, and further upon the vital statistics of the City of St. Louis, as I have studied and compared them with the vital statistics of other communi-
2314 ties.

* * * * *

Q. Would you say the same thing if the time required were five months?

A. I should say the same thing.

Q. Would you say the same thing if the time required were one year?

A. In that case I should want to know a good deal about the sediment and the particular conditions that prevail during that year. I can conceive of conditions that might destroy the germ en route during that time or even before that time, but I can as readily conceive of other conditions which might prolong its life, for example, the pouring of large quantities of acid from manufacturing waste down the canal during that year might conceivably destroy the typhoid germ in the water and in the sediment. ON THE OTHER HAND, THE POURING DOWN OF AN UNUSUAL AMOUNT OF ORGANIC MATTER FROM THE STOCK YARDS OR FROM SOME OTHER PLACE MIGHT SO ENRICH THE WATER AS TO SUSTAIN THE LIFE OF THE GERMS, PERHAPS EVEN LEADING TO A GREATER DURATION OF LIFE THAN
2315 THAT YOU HAVE STATED.

Q. Would you expect that under conditions existing on the Illinois River that typhoid bacilli turned loose into the Illinois River at the termination of the drainage canal would live for a period of fifteen months?

A. I should not expect very much about it. I should say that in regard to the period beyond a few weeks or months, that in general the mortality among the bacilli, among the typhoid bacilli, would be heavily, but that I should never feel certain, personally I should never feel certain even after one or two years, or possibly
2316 longer, that some of these were not living there.

Q. Eliminating the sewage of Chicago, what is your opinion as to whether such water would be suitable and safe for drinking and other domestic purposes in their natural state, or in the conditions in which they enter the St. Louis intake?

A. My opinion is that such waters would not be suitable or safe

for drinking purposes in their natural state or as they enter
2324 the intake tower of the St. Louis waterworks.
The system of purification prior to January 17, 1900, in St. Louis, was inadequate for purification.

2325 CROSS EXAMINATION,

By Mr. Todd.

Q. If it should appear that there are 788 cases of typhoid in the City of St. Louis in 1893, would that be a normal rate, while there would be only 215 deaths? * * *

A. That would not be a normal number of cases. It would be too small. The presumable number of cases from that number of deaths would be nearer 1,500 to 2,000, and all that means is THAT THE PHYSICIANS DID NOT RECORD THE CASES AS THEY SHOULD DO, AND ONLY THE MORE CAREFUL PHYSICIANS DOING THAT, THE UPSHOT IS WE SEEM TO GET A TREMENDOUS FATALITY, WHEN AS A MATTER
2327-2328 OF FACT IT IS ABOUT NORMAL.
I attribute the typhoid fever in St. Louis from 1895 to 1899 to a variety of causes—milk, oysters, dirty hands, infected foods,
2328 such as water-cress, celery, unwashed fruits, flies, etc.

2330 OYSTER EPIDEMIC.

The number of reported cases is a very uncertain measure of the amount of typhoid fever in any city in which the reporting is not very well done, AND WE HAVE EVIDENCE THAT THIS (ST. LOUIS) IS A CITY OF THAT KIND.

Q. Assuming that in 1899 the Board of Health of St. Louis sent out a letter requesting all physicians to report all cases of typhoid and a special effort was made to secure the data and the same in 1900 and 1901?

A. I am sorry to say that wouldn't materially modify my answer, thus far, because physicians are notoriously not obedient to the Board of Health, which requests them to do these things. * * *
I may say frankly that I do believe that a part of the rise in 1900 was due to the same causes which occurred at the end of
2333 1899.
The number of deaths from typhoid fever, for instance, in 1899 was 131 according to these (referring to Board of Health
2335 reports). * * *

Q. Suppose in 1890 there should be 277 deaths?

A. You mean 1900?

Q. 1890.

A. There were not. There were only 140.

Q. This chart (Ravold's chart) has 277 deaths.

A. I don't know anything about that chart. Here is the table of the Board of Health.

Q. This has been introduced in evidence and marked Complainant's Exhibit No. 22.

A. In 1890 the number was not so very high, according to this 140. It must be a blunder on that chart, according to the books. I GO ACCORDING TO THE REPORT OF THE BOARD OF HEALTH.

Q. Do you know from what months these statistics are made up?

A. This? (Referring to Board of Health Report.)

Q. Yes.

A. No, sir; I do not. They are published, I believe, by the Board of Health, and are such as I have used in my studying.

2336

Q. Typhoid fever may be contracted from kissing, may it not?

A. It is held that it may be.

Q. Do you hold it?

2341 A. Yes, I hold it.

* * * * *

Q. If the majority of these wells are located where there are outhouses and the inhabitants of these houses where the wells are situated use the water of these wells for drinking purposes, is there any way of estimating what effect these wells so situated will have upon the typhoid increase in the City of St. Louis?

A. I think that any expert, by a consideration of all of the circumstances, so far as he could learn them, and making careful inquiry of the changes as to the customs of the people before and after a given time, would be in a position to say after a given time whether any such increase was due to any such cause, whether any considerable part of such increase, I will say even any inconsiderable part, was due to such cause.

Q. Do you know whether such a thorough investigation as you have indicated has been made of these wells for the years 1900, 1901 and 1902 in the City of St. Louis?

A. I think so.

Q. By whom?

A. By myself. I have ascertained the number of wells. I have considered the question whether such number was materially

changed before and after. I have used my general knowledge of American communities and their behavior in regard to wells and water supplies. * * * I might even go farther and say that as between wells taken in a general and large way, and including a certain number of polluted wells, and a city water supply not above suspicion, it is by no means clear in my mind that the use of such wells would at any time increase the typhoid fever rate over and above the use of a water supply which was not entirely pure. I therefore exclude altogether the wells of the City of St. Louis as producing any important part of the increase in typhoid fever since January 1, 1900.

Q. Do you consider that the information which you have is sufficient to establish your conclusions beyond all reasonable doubt?

2342 A. I do.

Q. How many wells in the City of St. Louis have you investigated personally that outhouses drain into?

A. None.

Q. How many outhouses in the neighborhood of these wells within these three years have received the excrement of typhoid patients?

A. I don't know.

Q. How many people living in the houses where these wells are located and drinking the well water have contracted typhoid fever from them, if you know?

A. I have no means of knowing.

Q. In the absence of knowledge upon these three propositions, do you claim as an expert sanitarian that your conclusions in answer to my former questions were established beyond a reasonable doubt?

2343 A. I do.

The well water theory, however, has, in my judgment, been seriously overworked.

* * * * But the well water theory is, in my opinion, in the popular form of it at least, based largely upon insufficient evidence.

Q. If conditions exist in any of the wells of St. Louis where fissures appear, permitting the contamination of outhouses to enter the wells, such as you have indicated in part of your answer, have you investigated to ascertain whether that condition obtains or not?

A. I have not.

Q. If that condition should obtain, would you say then as a sanitarian that the water of that well would not establish the contagion of typhoid? * * *

A. That in my opinion, would be a serious menace to the health of the people drinking that water.

Q. Do you know whether in the 3,000 wells or more in the City of St. Louis that condition obtains in one or more wells?

2345 A. I do not.

Q. Now, as to the physical conditions and sanitary conditions in these wells, in any of these districts, has any one reported to you an investigation to ascertain their physical and sanitary conditions?

2351 A. No.

Q. Assuming that in these different districts where the typhoid was high in comparison with the other districts that there existed a number of infected wells, wouldn't that condition account for the typhoid in the City of St. Louis for 1900, 1901 and 1902?

A. It might if one were justified in making such an assumption and excluding from the same assumption the possibility of the occurrence of infected wells in other districts. Any such assumption, unless it covers the whole city, is a GRATUITOUS ONE, AND SUCH WELLS ARE NOT MORE LIKELY TO OCCUR IN ONE PLACE THAN IN ANOTHER. Besides, there is in no case in these districts any such excess as would lead to the expectation or to the supposition that any such infected wells had existed, and inasmuch, therefore as the assumption is, so to speak, entirely in the air, and does not include all the conditions which any assumption of this kind must include, I do not think that the larger number of typhoid deaths in certain districts can reasonably be accounted for in this way.

Q. But assume that an infected well exists out of this great number of wells in the City of St. Louis, in the absence of any personal investigation of all these wells by a man competent to pass upon their sanitary condition, you wouldn't consider as a gratuitous assumption, would you?

A. No, sir.

Q. If such a well should exist, and be connected with a dairy where the water from the well was used in diluting milk, could not that establish the disease of typhoid throughout the city if the milk was delivered to different houses and consumed by the people?

A. If the route of the dairyman covered the whole city or any considerable part of it, and the conditions were as you have stated, it is possible that an infection might be spread from such a source, but any milk epidemic produced in this fashion, if of an appreciable

size, is usually easy to discover, and there are not any of the
2352 earmarks of any such epidemic, so far as I have been able to
discover about the typhoid fever deaths in the City of St. Louis
during the years 1900, 1901 and 1902.

I have no doubt that the number of typhoid fever deaths and cases existing during the three years mentioned (prior to 1900) upon the water-shed above the intake of the St. Louis waterworks, which numbers would indicate perhaps between 3,000 and 4,000 cases annually, would render the water-supply of the City of St. Louis,
2360 if taken at the chain of rocks and delivered to the citizens
unpurified, somewhat unsafe and somewhat dangerous. * * *

Q. Assume, Professor, that you occupied the position in St. Louis as a sanitary engineer, and you were acquainted with all the conditions in regard to typhoid for the year 1897, 1898 and 1899 on the water-shed, as have been proven here in evidence, and have been included in the different hypothetical questions, both the ones put to you by Mr. Jeffries and the ones that I have presented to you, would you be able from your experience as a sanitarian, as well as a scientific man, to state what times, under conditions existing in St. Louis as they did those three years, in regard to its water-supply, when would it be safe for the citizens to use the water that comes from the intake and when would it not be safe, as explained in your previous answer?

A. No, I should not be able to state the times when it would or would not be safe under the conditions assumed.

Q. That being the case, would you, as a sanitarian, recommend to the citizens of St. Louis to use that water at any time during these periods, and recommend the same as being a safe drinking water?

A. I should probably not have recommended it for drinking purposes or as a safe drinking water at any time during that period without treatment and purification, inasmuch as one would never know, could never know, assuming that typhoid bacilli once found access to the river above in those large numbers,—could never know with any precision or certainty that these would have been effectually removed. Especially is this true with a water-shed of this character upon which a rain, limited as to the area upon which it falls, might
seriously affect the problem, and inasmuch, further, as the
2362-63 stirring of sediment by steamers, or by fishermen, might at
times convert what would at other times be a well purified flowing stream into one laden with danger.

RE-DIRECT EXAMINATION.

MR. JEFFRIES: Assuming that the water-supply of the City of St. Louis has been treated in the same manner since 1895, what, in your opinion, was the sanitary condition of the water-supply of that city after treatment for the years '95, '96 and '97, based on the typhoid fever death rate of the city for these years?

A. My answer is that, judging partly by my knowledge of the methods of sedimentation employed, but chiefly by the typhoid fever death rate in St. Louis during those years, that the sanitary
2398 condition of the water-supply as actually delivered to the citizens during those years was good.

RE-CROSS EXAMINATION,

By Mr. Todd.

Q. Professor, in the question put to you by Mr. Jeffries, I believe it was, the second in regard to the years '95, '96, '97 and '98 and '99, based upon the typhoid conditions in the City of St. Louis, you stated that the water-supply from a sanitary point was good. What did you mean by the word "good" in that sense?

A. I meant that it must have been of such quality as to have probably produced little or no typhoid fever.

Q. Is the word in the sense you used it safe and drinkable, the word "good"?

A. I should have considered it so, in view of the facts.

Q. And you took into consideration all the facts in connec-
2417 tion with typhoid for those years, did you?

A. I did.

Q. Professor, do you know whether the health department of the City of St. Louis has ever examined any of the wells located in the City of St. Louis for the purpose of ascertaining their sanitary condition?

A. I do not know, but even if they had I should not feel certain as to the results of such examination, because in the present state of the art, as I stated this morning, it is often impossible to tell
2363 by ordinary methods of examination whether a well is or is not safe for drinking purposes.

Q. In your investigation, to what did you attribute the condition of typhoid in the City of Chicago?

A. Chiefly to the pollution and infection of the water-supply, although of course the usual factors of secondary infection, milk and

the like, we also consider. * * * I should be glad to read in support of this position if it is proper to do so.

MR. TODD: I don't care to do that. I just wanted to ask you a preliminary question.

(Then follows the attempt of the witness under protest of counsel to read and inject into the record a copy of the report
2365-66-67-68-69-70-71 when he knew and was so informed by counsel that he was not asked to read the report in evidence, but he insisted upon doing so.)

Q. An anti-kissing society would be a good thing, too, wouldn't it?

2375 A. I think that it might restrict the spread of various diseases, though I have no great expectation that any such will be formed.

Q. Will the sewage which enters the Illinois River at Peoria purify itself within 25 or 50 miles, in your judgment?

A. To a certain extent, yes, but not to such an extent that
2377 I should consider the stream into which it was poured fit for drinking purposes.

I have already testified, I think, to the fact that I did not regard the Mississippi water previous to the opening of the drainage
2379 canal as it arrived at the chain of rocks as suitable for a modern city, but as to less or more I cannot say without a very careful investigation.

RE-DIRECT EXAMINATION.

By Attorney General Crow.

COST OF FILTRATION.

The question, as I remember it, was in regard to purification by filtration, and my answer was that the cost would probably not be materially increased by the addition of the population and infection derived by the City of Chicago or the opening of the drainage canal. On reflection, however, I realized that I did not take into consideration with sufficient care the fact that aside from the masses of filth that might be washed down on certain occasions, such as freshet periods, and which might add somewhat to the cost of the cleaning out filter, and caring for the same, a cost which might or might
2382 not be a material increase in the conduct of these filters, according to the importance attached to the word "material," etc.

Q. You stated in your cross-examination, in answer to a question asked you, that you thought perhaps that the typhoid increase in December, '99, did reach over into 1900; I will ask you to state, if you know, how far into 1900 that reached, if you have any idea as to how far it reached? * * *

A. Because while in 1900 there were 19 deaths from typhoid fever, which was a larger number than had happened in January for several years at least, in February the number of deaths was only five, which was a smaller number than in '97, '98 or '99. This, in my judgment, shows that the little outbreak at the end of '99, whatever it may have been due to, had spent itself, while the occurrence of sixteen deaths for March, 1900, has been attributed, and, I believe, properly attributed by Dr. Ravold to the opening of the drainage canal on January 17th. AT LEAST A PART OF THAT INCREASE MAY HAVE COME AND PROBABLY DID COME FROM THAT SOURCE. On the other hand, the deaths in the next month fall off again to four, which was lower than during the two previous years, so that it is not easy to absolutely be sure that the number sixteen did really come to any great extent from the first arrival of the material held in the drainage canal. I may add that it is only by taking these facts IN A LARGE WAY, and for considerable periods, that any safe conclusion can, in my judgment, be drawn.

Q. Professor, after sewage which is infected with bacilli of water borne diseases is placed in running water, is there any absolute safety in using that water afterwards for drinking purposes within a month's time?

A. Broadly speaking, I do not think there is. * * * In
2397 matters of this kind we must take the statistics in a broad way and cover considerable periods of time if we wish to be absolutely sure.

Q. While it is evident to your mind that at any time in the last ten years the water-supply of St. Louis ought to have been filtered?

A. Broadly speaking, I should say yes, although, as I have just answered a question of Mr. Jeffries, there perhaps have been times when the city did get on remarkably well without it, but I think that it ought to have been filtered even then.

Q. Well, if you have any opinion as to what proportion of that expense should be attributed to the waters of the Illinois state your opinion. (In regard to cost of filtration.)

2401 A. I have not any. At least I have not anything worth stating in figures.

GARDNER STEWART WILLIAMS.

2418 DIRECT EXAMINATION.

2419-20 Qualifications.

Q. Professor, can you estimate the amount of human feces discharged daily into the Chicago sewers?

A. Yes, in the neighborhood of 4,400 cubic feet, or about 150 tons.

Q. How does that compare with the suspended solid matters at Lockport?

2422 A. It amounts to something more than 50 per cent. of the suspended matter of Lockport, as appears from analyses there.

Q. How is the character of this liquid discharged into the Desplaines River at Lockport changed by the time it reaches Grafton, on the Mississippi River?

A. It is changed by the dilution with the waters reaching the Desplaines and the Illinois Rivers from other sources by the
2424 effects of sedimentation along the line of the stream and by the action of the vegetation along the same.

Q. Then, Professor, it would follow as a result of your statement, in your opinion, that the bacteria contained in the wa-
2427 ters would be less likely to be deposited than would the inert mineral water?

A. There is no question about that being the fact.

That it is an observed fact that rivers did out again in times of flood the channel which they have previously flooded up during low water stages, and if this were not so, the rivers would ultimately fill themselves up, and in the case of the Illinois River the observations of the United States engineers who have had charge of the improvement of that river show that there has been no extensive silting, but rather filling of the channel of the stream, either natural or artificial. In fact, Mr. Jordan states in a paper which he has recently published that he was remarkably struck with the fact that there was no apparent deposit on the bottoms resembling such
2428 deposit as would be expected from sewage polluted matter in stagnant waters.

The effect of times upon the scour and upon the sediment along the bottom of the stream is very interesting. The current set up behind the dam tends to cause a rolling over of the particles
2428 of suspended matters in the water very much as snow drifting against a fence will roll and toss, etc.

It is also observed that even a boat stationary in the stream caused disturbances of flow which leads to the scouring of bottoms beneath it, and at its sides, so that the effect of boats in the
2430 Illinois River cannot fail to be a very important factor in the disturbance of the sedimentary deposits that may be formed along the bottom, both in high and low water.

Q. Do you consider, Mr. Williams, that germs of typhoid fever coming from the sewers of Chicago, and passing by way of the drainage canal into the Desplaines and Illinois rivers, that might be deposited in the bed of these streams and remain there for a considerable period would be entirely destroyed?

A. That, of course, would depend upon the length of time which the bacteria might remain deposited in the bed of the stream, but under such conditions as existed upon the Desplaines and Illinois rivers receiving the sewage of the City of Chicago, I see no reason to believe that germs deposited in the bottom of the stream would be destroyed under existing circumstances.

Q. Mr. Williams, do you consider it possible that the water of the Illinois River in times of flood might contain, as a result of a scouring action upon the deposits in the bed of the stream, more infectious and dangerous material than that ordinarily present in the diluted sewage entering the Desplaines River at the bear-trap dam at the foot of the drainage canal?

A. It seems entirely possible that as a result of the scouring action set up upon the bottoms of the slack water portions of the Illinois River, the water in times of flood might be more heavily charged with polluted and infectious matter than is the diluted sewage delivered into the Desplaines River at the bear-trap dam.

Q. How much of a rise of water would you consider necessary to produce a scouring of the sedimentary deposits in the Illinois River?

A. If water were just flowing from the tops of the dams I should consider that a rise of half a foot would be sufficient to set up for an appreciable scour, and at many places on the stream a
2433 rise of very much less than this would undoubtedly change the conditions of equilibrium along the bottom and cause the resuspension of previously deposited matter.

I have made estimates, and it appears that we may expect the water to travel this distance from the bear-trap dam at Lockport to the mouth of the Illinois River under different conditions existing in the stream in from one to three weeks, speaking generally.

Q. Have you made any estimates as to the number of days in

the year 1900, say, in which the water coming from the bear-trap dam at Lockport, would reach the mouth of the Illinois River within, say fifteen days or less?

A. I estimated that in 1900, during something over 300 days,
2434 water would have flowed from the bear-trap dam to the mouth of the Illinois River in less than fifteen days.

Q. Mr. Williams, what effect upon the quality of the Mississippi River at Grafton, Illinois, has a discharge into it of the Illinois after the latter river has received the mixture of Chicago sewage and water at Lockport?

A. It tends to increase the pollution and infection of the water of the Mississippi River and render it less safe for use for drinking and household purposes below the mouth of the Illinois River.

Q. Mr. Williams, supposing all diseased germs and infectious matter in the diluted sewage of Chicago, as it passes Lockport, should be rendered or become inocuous at and from that point, would you then consider the discharge of the waters of the drainage canal into the Illinois River in any way dangerous to the health of the people of Missouri using the water of the Mississippi River for drinking purposes below the mouth of the Illinois River?

A. Even under such circumstances I should consider that the discharge into the Illinois River of the quantity of water now delivered through the Chicago drainage canal would be a menace to the health of the people of Missouri using the water of the Mississippi River below the mouth of the Illinois for drinking purposes, for the reason that this quantity of water added to the stream during the low water period tends to materially decrease the time required for the flow of the water from various points along the Illinois River, where pollution and infection may be, and are added to the stream, and thereby increase the liability of such pollution and infection
2437 reaching the Mississippi River in condition to do injury and harm to the citizens of Missouri who may be using the water.

A. For something over 300 days in the year water would
2437 reach the intake of the St. Louis waterworks in from nine to fifteen days' time after it left the bear-trap dam.

From sixty to ninety days in each year the water of the Chicago drainage canal would probably arrive at the Mississippi River
2438 at the chain of rocks within ten days of the time that it passed over the bear-trap dam.

Referring to the water of the drainage canal, this question was asked:

Q. Mr. Williams, do you know of any case where a similar

diluted mixture of suspended solids from sewage matter has produced typhoid fever?

A. I do. I have personal knowledge of the facts in question, inasmuch as I investigated the outbreak of typhoid fever in Detroit, which followed the occurrence to which I have referred. The water supply of the City of Detroit is drawn from the American channel of the Detroit River, at the foot of Lake St. Clair. The water from Lake Huron flows through St. Clair River, a distance of thirty-five miles to the delta of the St. Clair, and empties into Lake St. Clair. Lake St. Clair is twenty-four miles in diameter. In 1890 typhoid deaths in Detroit were 39. In 1892, 209. This epidemic began in June, during which month there were 38 deaths. I started to ascertain the cause of this epidemic. I found that the epidemic was undoubtedly caused as a result of improvements to the channel of Black River, which flows into St. Clair River at Port Huron, a distance of fifty-seven miles from the intake of the Detroit waterworks. The Black River was a sluggish stream, having ordinarily no current, only in times of heavy rain a perceptible current; was receiving the sewage of Port Huron. The United States Government had caused the river to be dredged during the early months of '92, removing deposits
from the mouth of sewers which range from a foot to seven
2440 feet in depth, and as much as ten feet in depth. The material
was dumped into the stream fifty-seven miles above the intake of the Detroit waterworks.

This highly infectious deposit of material was reached right at the beginning of the operation in 1892, so that this fully explained the strong outbreak of typhoid fever in Detroit, it having been carried through the water of the St. Clair River, and through
2441 Lake St. Clair to the intake of the Detroit waterworks, thence
distributed to the consumers throughout the city, with the results above mentioned. The current in the St. Clair Lake is not
perceptible to the eye.
2443 The time required was not less than eight days, and would
have arrived there in twelve or fourteen days.
Seventy-five per cent. of typhoid cases will incubate in from
2444 ten to fifteen days' time after infection is taken.

I found that, making the allowance already stated for the time required for the infection to come from the point at Port Huron to Detroit, allowing for incubation, allowing time for the patient to
die, the sum of such times agreed within twenty-four hours
2445 with the time which had elapsed from the deposit of the
dredged material and the time when there were four deaths from typhoid fever in Detroit.

There had been typhoid fever in Port Huron during Septem-
2450 ber and October, 1891, as shown by the records of the State Board of Health of Michigan, which facts have been communicated to me by the Secretary thereof.

Dredging began April 16, 1892, and the work continued all
2451 during the year, but the work of the particularly infectious matter ended in a comparatively short time, a matter of a few weeks.

After the most careful investigation which it was possible for me to make, which included conversations with physicians who treated cases during this epidemic, the studies of rainfall, general precipitation and temperature, of the distribution of cases throughout the city with relation to possible infection from previous cases,
2454 and a consideration of all other suggested sources of typhoid infection, it was impossible for me to find any cause which could explain or begin to explain such an outbreak of typhoid as occurred in the month of June, 1892.

In consideration of the fact that the most recent known cases of typhoid fever preceding the time of the dredging in the Spring of 1892 at Port Huron and those reported in September and October, 1891, to the Michigan State Board of Health, and in view of the fact that inquiries of the Board of Health of Port Huron and of the health officials of said city and of leading physicians there, failed to establish the existence of typhoid fever in Port Huron, subsequently to that time, and previous to the beginning of the dredging in the Spring of 1892, I am entirely satisfied that some of the
2458-59 infection in the sewage matter dredged in 1892 had remained or lived in that material for three or four months at least, and I think it entirely possible that much of it had lived a very much longer time.

I am convinced that they (meaning the typhoid in Detroit) were very largely caused by the stirring up of the material on the bottom and sides of the St. Clair River, and Lake St. Clair, and at the head of the Detroit River itself, which had come there as a result of the dredging of moderately infected material at the mouth of
2460 Black River during the Fall of 1891, AND HAD REMAINED ON THE BOTTOM OR IN THE LAYER OF WATER ADJACENT TO THE BOTTOM DURING THE INTERVENING PERIOD.

It is my opinion * * * that typhoid infection or typhoid germs have at times come from Chicago to the intake of the St. Louis

waterworks, that they may and will continue at times to do
2461 so under the conditions which exist and which may be expected to exist in the streams aforesaid.

I should say that the evidence afforded by the typhoid fever statistics of St. Louis for the period mentioned ('95 to '99) indicates that while the water supply of St. Louis at this time was not ideal, it nevertheless would compare favorably with that of a very large number of our American cities, and that, generally speaking, it would entitle the St. Louis water supply to rank with about the second class of American water supplies as water supply experts usually consider
2462 them.

Q. I will get you to state if, in your opinion as an expert, you have found anything in these statistics (meaning typhoid statistics on the Mississippi, the Illinois and Missouri rivers) mentioned in your last answer that would account for the large increase of typhoid fever in St. Louis since the 17th of January, 1900?

2462 A. I have not.

It is my judgment that to the discharge of sewage by the Sanitary District of Chicago is attributable the major part of the increase in typhoid fever revealed by the typhoid statistics of the City of St. Louis since the beginning of 1900, as compared
2463 with the former period.

Q. Assuming that the number of bacilli coli communis in the waters of the Illinois River at Grafton are at intervals no greater than the number contained in it before the opening of the Drainage Canal, do you consider for that reason that the water is at all times no more dangerous than formerly?

A. Most certainly I do not.

Q. Mr. Williams, I will ask you, as an expert on water supplies for cities and towns, basing your opinion upon the subject BROADLY, in your judgment is there any present or impending or future danger to the people of the State of Missouri using the water of the Mississippi River below the mouth of the Illinois for drinking purposes, which danger would be due to the discharge of the mixed sewage of the Sanitary District of Chicago, and the waters of the Drainage Canal into the Illinois River, other than the infection with typhoid germs of the waters with the Mississippi River?

A. In the history of water-borne diseases in America, while typhoid fever plays an important part, it comes far short of playing the entire part. Not only Asiatic cholera, but a large number of our common American diseases, are undoubtedly transmitted through the water. Among those germs which have been found to have a con-

siderable length of existence in water are the germs of diphtheria, tetanus and anthrax, as well as a considerable number of germs which are derived from the diseases of the lower animals. * * *

Should anthrax be present among cattle which are daily slaughtered in the Chicago stock-yards, and from them be transmitted from the nostrils, mouths or bowels of these animals—be transmitted into the sewers of Chicago, THERE WOULD BE NO QUESTION THAT THE GERMS OF ANTHRAX MIGHT REASONABLY FIND A LODGING IN THE PEOPLE OF MISSOURI, WITH EXTREMELY FATAL RESULTS. * * * The disease of glanders is another source of danger to the inhabitants of Missouri. * * * It seems to me that the danger impending over the citizens of Missouri as a result of the discharge of the sewage of Chicago through the Drainage Canal into the waters of the Illinois River is a most fearful menace to the health and welfare not only of the citizens of Missouri, but of the citizens of other cities below the mouth of the Illinois River, leaving entirely out of consideration the question of typhoid fever.

2468-69 Q. As to whether any expert can give a different opinion from himself upon the subject which is asked of Professor Sedgwick, he made the following answer: "If, with the knowledge of the existence of the conditions at Chicago and along the Drainage Canal, the DesPlaines River and the Mississippi River, that are known to me to exist, an expert should state that it is possible for infectious matter discharged by the sewers of Chicago to reach the Missouri shore of the Mississippi River, and the intake of the St. Louis waterworks at the chain of rocks, and to be a source of danger, etc. * * * I should say that he had thereby shown such lack of knowledge of the history of water-borne diseases and the life and phenomena connected with their transmission and infection, as well as the laws of flow in open channels, as to totally disqualify him as an expert upon the sanitary value or quality of a public water supply."

2473-74 I would attribute the increase of typhoid fever in St. Louis to the opening of the Drainage Canal.

2481 The Ithaca epidemic.

The Charlevoix epidemic, in 1897.

2484-85 CROSS-EXAMINATION,

By Judge Johns.

Q. When did you investigate the epidemic of typhoid fever which appeared in Detroit in 1892?

A. From 1895 to the present time.

Q. At the time of the epidemic you made no kind of inves-
2487 tigation of it?

A. No, sir.

Q. When you commenced this investigation in '95 had you discovered from the literature in reference to typhoid fever that
2490 any cases of typhoid fever had in that literature been attributed to a greater distance than thirty miles?

A. So far as I recall, I have no knowledge of a case where the infection was attributed to a travel of more than thirty miles in a water supply.

Q. Then, you had in 1895 no knowledge whatever from your personal investigation as to the transmission of typhoid germs in running water?

A. I think I had as much personal knowledge of transmission of germs in running water as anybody else could possibly be said to have, if you restrict the personal knowledge to the actual observation of the transmission of the specific germ.

Q. Had you up to 1895 investigated any of the facts and conditions by which you afterwards arrived at the conclusion that disease of typhoid fever was caused by the transmission of typhoid germs in running water?

A. Up to the middle of 1895 I had not.

Q. Then, when you commenced the investigation in 1895, as to the cause of typhoid fever in Detroit in 1892, it was a new branch of civil engineering to you or water engineering and supplies?
2491 A. I think it may be so considered.

Q. Where did you learn that the harbor of Port Huron had been dredged?

A. At the meeting of the Detroit Engineering Society, held at the Hotel St. Clair in Detroit, was the first I knew of it.

Q. At what time?

A. I think it was some time in '96, or possibly in 1897.

Q. So that the first you knew that the harbor of Port Huron had been dregded was in 1896 or '97?

A. Yes, sir.

2492 Q. Did you go to Port Huron in 1896 to investigate the dredging done there in 1892 or '91?

A. No, sir.

Q. Did you ascertain in Port Huron the number of cases of typhoid fever or deaths from typhoid fever in 1890 or in the preceding year?

A. As I remember the matter now, there were no records available in 1890 or during the preceding years.

Q. Were there any records available in 1891 at Port Huron as to the deaths from typhoid fever?

A. The records in 1891, I believe, were obtained from the Michigan State Board of Health.

Q. How the Michigan State Board of Health obtained it you don't know?

A. They obtained it from the report of the health officer or person in Port Huron reporting the appearance of typhoid to them.

Q. Whether that report was correct or not you do not know?

A. I centainly do not.

Q. Do you know how many cases of typhoid fever there had
2493 been in Port Huron in 1891 prior to November?

A. My recollection is there had been two cases reported.

Q. Do you know how many cases had been reported in 1890 during the entire year?

A. I don't know. My impression is there had been none reported.

Q. Do you know as to 1889 or any preceding year?

A. I don't know * * *. When I began this investigation I didn't know of any deaths in Port Huron from typhoid fever.

Q. And you do not know of any now, do you?

A. I was not personally acquainted with any person who died from typhoid fever in Port Huron.

Q. Do you know from the records, and, if so, from what records, of the existence of typhoid fever in Port Huron prior to November, 1891, with the exception of the two cases which you recall?

A. I do not.

Q. So that absolutely you never did know, and do not now know, whether there were more than two deaths from typhoid fever in Port Huron prior to November, 1891?

A. I don't know.

Q. Were these cases deaths or merely sickness?

2494 A. I don't positively recall, but my impression is they were cases, not deaths.

Q. During the summer seasons are not the flats of Lake St. Clair, its marshes, frequented by from 2,000 to 3,000 people daily at the resorts and in the club-houses and in the occupation of fishing?

A. That is a larger number than I should estimate were there.

Q. So that there is a considerable number of constantly changing population upon Lake St. Clair during the summer season?

A. Yes.

Q. Or upon the upper portion of Lake St. Clair, that is, upon the delta of the St. Clair River, and the dejecta of these people goes directly into the water, doesn't it?

2499 A. I think that is generally the case. In fact, I know of no other disposition of it.

Q. What amount in cubic feet would there be in Port Huron for one year of excreta discharged into the sewers?

A. I will not be able to answer that question, because I am not informed of even approximately the number of people who use the sewers of Port Huron, and, therefore, it would be impossible for me to make an estimate in answer to the question.

Q. Had you in 1890, '91 or '92 sufficient familiarity with the City of Port Huron to make a guess in reference to the number of people whose sewage was discharged into the sewers of Port Huron?

A. I think not.

Q. Then, as to the volume or amount of such discharges you

2505 have no kind of an idea?

A. No, sir; except that there were such discharges.

Q. Would you say in your best opinion that it would be fair to estimate that 5,000 people discharged their household sewage into the sewers of Port Huron in '90 and '91?

A. I think it is possible. * * *

Q. If such assumption is fair, what amount in cubic feet would you estimate there was of excreta discharged from these 5,000

2505 people, making the estimate upon some basis which engineers or sanitarians assume?

A. Oh, between 6,000 and 7,000 cubic feet.

Q. How many cubic yards would that be?

A. Oh, about 230 to 250, or less than one-half or about one-half of the amount that was usually dredged in a day during the dredging of the Black River in 1892.

I should expect it would be fair to make a division of the amount that I have computed by six to get the probable delivery of the two months of the year in question.

Q. Or substantially, in round numbers, forty cubic yards in the two months?

A. Just about that, substantially; yes, sir.

2506 That was 10,600 yards, substantially, in round numbers, in April and May, of dredged material.

Q. Of the assumed 10,600 yards of material dredged from the harbor of Port Huron, some forty-odd cubic yards might possibly be

a fair estimate of the amount of solids in the household sewage coming from the bodies of persons using the sewers of Port Huron?

A. I would say that I think that forty cubic yards, or about 15,000 yards, would be a correct statement of the case, or an approximately correct statement of the case.

Q. Well, assuming that the sewage discharge of the kind spoken of,—household sewage in solids, was 230 to 250 cubic yards per year, you would have a fair estimate, you think, of the solids in
2507 cubic yards for the City of Port Huron during the year?

A. I think it is a reasonable estimate.

Q. If such a body of water were regularly and continuously polluted, one part in 1,000,000 of the many cubic feet of pollution would have to be put into the water each day to make one part?

A. On that assumption, 15,552 cubic feet.

Q. That is to say, in order to regularly, systematically and scientifically pollute the body flowing past Port Huron into St. Clair, for one day of twenty-four hours, there would have to be 15,552 cubic feet of polluted matter to make one part in a million pollution?

A. That is correct.

Q. What per cent. of pollution of 933,120,000,000 cubic feet of water is forty cubic yards of solid material, stated in parts per million?

A. About 108 ten-thousandths of one part per million.

Q. Do you want to be understood as saying, on the basis of these figures, that if there was the dejecta of two typhoid patients put in some time about the 1st of April, 1892, in forty cubic yards of solid sewage from the bodies of people in 933,120,000,000
2510 cubic feet of water, which would travel fifty-seven miles, that that dejecta would pollute the entire body of water during any considerable portion of that time, or any portion of it?

A. Considering the fact that the number of bacteria found in the excrement of typhoid patients has been on the average about 200,000 million per day, and that if these patients were sick with typhoid fever and recovered, they would each have been discharging that excrement, so charged with infection, for a period of sixty days; and, considering that there were assumed to be two patients, we find that there would have been probably discharged into the sewers of Port Huron, and from there possibly into Black River, and the material dredged therefrom 24 million milloin bacteria, which would have been sufficient to have put about twenty-seven bacteria into every cubic foot of water discharged under the conditions assumed; and it, there-

fore, seems to me possible that the infection mgiht have been
2511 so distributed.

Q. Does it, therefore, seem to you probable?

A. I think it is within the realm of probability.

Q. Then, assuming that the volume of water in the St. Clair River passing Port Huron in a day was 15,502,000,000, what per cent. of it was pumped into the Detroit water-works?

A. Three one-hundredths per cent., I think.

Q. Twenty-seven bacteria of typhoid bacillus to a cubic foot of water would be about four individual, separated bacteria, roughly speaking, bacteria to a gallon?

A. Yes.

Q. Assuming that the number of bacteria you have mentioned, namely, twenty-seven, to a cubic foot of water, was equally distributed throughout the entire volume of water flowing out of the St. Clair River into Lake St. Clair, and therefrom through the Detroit River to the intake at Detroit, do you want to be understood as saying that these four bacteria in a gallon of water traveled fifty-
2512 seven miles, would live and be virulent?

A. I see no reason why some of them might not live and be virulent.

(Then follows his reasons for his opinion.)

Q. Do you know when these two people died of typhoid fever in Port Huron?

A. I don't know that they died.

Q. You have heard that they died. Do you know, then, whether these two cases of which you have heard recovered?

A. I don't know.

Q. Do you know whether the discharges from their bodies were cast into Port Huron?

A. I do not.

Q. Do you know whether the discharges from their bodies were destroyed?

A. I do not.

Q. Or disinfected?

A. I do not.

Q. Without stating what you have in your mind, do you wish
2513 to be understood, as a sanitary expert, epidemiologist and sanitary engineer, that under the facts and figures elicited by your cross-examination you are still of the opinion that typhoid fever resulted from dredging of the harbor of Port Huron and the mouth of the Black River in 1892?

A. I wish to be understood as saying that it is my belief that the typhoid fever in 1892 was very largely caused by the dredging of the Black River in Port Huron during the same year.

Q. Is the Detroit case regarded as a classic in sanitary science?

A. I couldn't say.

Q. Are you responsible for the story going about in scientific and sanitary circles concerning the epidemic of Detroit and
2514 its origin?

A. I don't know what story is going about in sanitary circles concerning that epidemic. I investigated that epidemic and the results of my investigation have been given here.

2517-18-19-20 Crookstown epidemic.

Charlevoix epidemic.

2524–26–27 Q. Might possibly have come in from as far as Ann Arbor?

A. Yes, or any other place. In fact, there were various ways in which typhoid fever might have gotten into that water. It evidently was in the water and that was the most obvious way in which it could have gotten in; and, while I do not pretend to say that that was the cause of this outbreak, it strikes me that it was presumably the cause, while I do not know particularly, but as long as it
2530 was satisfactorily established that it was the water that caused it, I didn't proceed to scrape the country with a fine-tooth comb to see that all other possible sources were eliminated.

Q. Have you been up the Illinois River at a time of ordinary stage water?

A. I have not at any time or any stage of water.

2534 Q. Not in the vicinity of the river?

A. No, sir.

Q. Are you familiar with the surafce flow in various stretches of the Illinois River; for instance, do you know the fall of the
2535 Illinois River from Ottawa to Lacon?

A. I am not certain that I have any information on the fall of that particular reach.

Q. Have you any definite idea, derived from your personal experience or your reading, in whatever way, as to the length
2538 of time that a typhoid bacillus might live in the sedimentation of the Illinois River?

A. I have not.

Q. Have you, or has any other scientist, any kind of positive knowledge as to the length of time that any given lot of typhoid bacilli lived in sedimentation? Now, I mean of positive knowledge?

A. You mean actual experimental knowledge?

2539 Q. Yes, anything more than suppositions.

A. I am unable to cite a case of specific experiment and at the present moment do not recall one.

Q. Does a bacillus examination, as a rule, determine whether

2545 water is infected?

A. Not absolutely. In fact, generally not.

Q. In their natural state, considering the future, the untreated waters of theMissouri River will be necessarily a menace to the inhabitants of St. Louis, as the waters came into the intakes, would they not?

A. I should not think that the waters of the Missouri River in their natural state, either in the present, past or future, would be a menace, but if you mean with the growth of population upon the Missouri water shed, it would contribute additional infection to the Missouri River and cause it to become less healthful, and less safe, as a water supply; I am perfectly frank to answer yes.

Q. And that answer would apply, also, to the waters of the Mississippi River?

A. Yes, sir.

Q. Are there other persons, sanitary engineers, experts in water supplies in this country, who are as familiar with the subject as yourself?

A. I think there are not very many.

Q. About how many?

Q. At the present moment I do not think of any whose judgment I would take in preference to my own, or whose judgment I would advise a client to take in preference to my own.

Q. If it could be imagined that some gentleman who had the experience and qualifications equal to your own and had made the same amount of examination and study of the conditions embraced in this entire case, should come to an opposite conclusion to yours, would you consider that that person exhibited an ignorance of the conditions and of the subject which would make his opinion of no account?

2546–47 A. That would be the conclusion I would have to draw from the evidence in the case.

Q. Can you conceive of any distance in a running stream in which typhoid fever bacteria might not live in the waters of that stream?

A. The life of a typhoid bacillus in stream is rather a question of time than distance, and as a general proposition I would say that

it is my present opinion that there is no stream of water on the surface of the earth flowing in natural channels that is long enough to warrant the absolute assurance that a typhoid germ might not live from one end of it to the other.

Q. So, if there were typhoid germs cast into the waters of the Mississippi River at St. Paul, and no other possible source of infection of these waters, do you believe that those typhoid germs might arrive at New Orleans and infect the water supply of the City of New Orleans?

A. I think it is possible, to a certain degree. That is, I
2259 think it is possible that some of them might arrive. I do not want to be understood as saying they might all arrive.

Q. Did you ever hear or know of an instance in which the infection of a water supply was attributed to an infection in the fifty miles above the place where the infection was found to exist, except
2551 in the case now under investigation; and, if so, where and how did you hear of it?

A. I do not recall of having heard of any such case at the present moment. That is, no such specific case.

2551 CROSS-EXAMINATION,

By Mr. Todd.

Q. And that the period from the deposit of infectious material to the four deaths occurring, corresponded within twenty-four hours, you said, of the time allowance for incubation?

A. For the transmission, incubation and death.

Q. How long had these patients been sick with typhoid fever?

A. I couldn't say.

2553 Q. How long after a person contracts typhoid fever before they pass the danger point?

A. That's rather hard to say.

Q. Well, now, knowing how long these four patients had been down with typhoid fever before they died, how did you make your conclusions as to the time of incubation between the deposit and their death, as upon an accurate judgment?

A. Well, having made a study of the statistics of some thousands of typhoid cases, and determining therefrom the ordinary average period elapsing from the time of infection to the time of death, or from the time of taking down to the time of death, and finding the average period in a very large number of cases of typhoid, I felt

warranted in assuming and applying that period to the cases in question.

Q. Regardless of knowing whether these patients had been sick for two or three months prior to death or not?

A. Certainly, sir.

Q. Assuming it is not an improbability or an impossibility that the date of the four deaths under consideration had occurred after an illness of say two or three months' duration, would that make any difference in your conclusion?

A. I think I can safely eliminate those four deaths without
2554 violating my conclusions or causing me to change my view in the matter.

Q. Have you enunciated and demonstrated any new principles (as a sanitarian or epidemiologist)?

A. I don't know that I have.

Q. Have you been the pioneer in any new departure in any new investigation of this science?

A. I should hardly want to claim that I have.

Q. Has this science of epidemiology and sanitary engineering as to water supply been exhausted?

A. I rather think not.

Q. Do you know of any one in this country or elsewhere that has made more extensive investigations than yourself?

A. I think there are such persons.

Q. If such a person, in consideration of these facts, should draw different conclusions from those which you have drawn, would
2555 you consider his conclusions unworthy of acceptation?

A. Unless they were possessed of other facts which are not known to me, I would certainly consider they had made a mistake.

I have studied the typhoid statistics from '96 to '99 upon the water shed, and the presence of such cases would undoubtedly render the water supply of St. Louis unsafe and dangerous for domestic use, for even though the water was treated by what we know to be and what analyses have shown was an efficient method of treatment, the typhoid fever death rate and the number of cases of deaths in St. Louis apparently traced to water infection, is greater than should exist attributable to a good water supply; and, knowing the conditions that obtained prior to the opening of the Drainage Canal, I should certainly not have recommended it as a safe water without
2557 boiling, filtration or some treatment that would be sure of certainly reducing the possibility of infection from it.

Q. If conditions existing between Minneapolis and St. Louis

were such as to be the cause of the typhoid in St. Louis, and similar conditions existing between Kansas City and St. Loius were such as to have Kansas City the cause, if these two conditions in Minneapolis and Kansas City existed at the same time, is there any way known to science of waters that can demonstrate whether the cause of typhoid fever in St. Louis came from Kansas City and not from Minneapolis, or from Minneapolis and not from Kansas City?

A. Not from my knowledge. That was the answer that I intended to give to the question before.

Q. Is there any way of scientifically demonstrating the proportionate share of the increase of typhoid fever in St. Louis over any of these cities, without assuming something?

A. It seems to me that it may be demonstrated without an assumption.

Q. What proportion did Minneapolis contribute to the increased typhoid fever in St. Louis in 1900?

A. I couldn't say.

Q. Couldn't you say what proportion any of the cities contributed outside of Chicago?

A. I doubt it. I think not.

2561 Q. Can you show what Chicago contributed, without assuming anything?

A. Not the absolute quantity.

Q. Do you know whether the same territory that empties into the Chicago River, the 4,400 cubic feet of solid fecal matter, is any different to-day from what that same territory was prior to the opening of the Drainage Canal?

A. I couldn't say at the present moment positively.

Q. Do you know how much or what proportion of that 4,400 cubic feet was pumped into the Illinois and Michigan Canal at the Bridgeport pumping works, prior to January 17th, 1900?

A. No.

2564 Q. Have you any judgment in the matter based upon any accurate knowledge?

A. I don't know that I have at the present moment.

Q. Do you know the amount of infection that came from any other one source before the opening of the Drainage Canal?

A. Oh, no.

Q. How deep is the Chicago River, if you know?

A. My recollection is that it is somewhere around sixteen or eighteen feet, possibly.

Q. What effect did the sewage pumped into the Illinois and

Michigan Canal prior to the opening of the Drainage Canal have upon St. Louis?

A. I don't know.

Q. How much of the typhoid of St. Louis would have been
2567 attributed to the discharge of the Chicago River through the Illinois and Michigan Canal prior to the opening of the Sanitary District?

A. I couldn't say.

Q. Suppose that the number of cases as testified to upon the chart that is offered by Dr. Ravold, in 1900, was 1,213 cases, and in 1901 was 1,101 cases, and 1902 was 1,112 cases, which would be the most scientific way to consider the question of typhoid increase, in deaths or the increase in cases?

A. The increase in deaths.

Q. A man frequently has been accused of dying of typhoid, when, as a matter of fact, he didn't have it, hasn't he?

2568 A. Oh, certainly; and so there have been other cases where he died of other causes and they thought he had typhoid.

Q. So it leaves the whole situation in doubt, doesn't it?

A. To a moderate extent; but, considering these facts from a BROAD, practical standpoint, these things will balance up in a period of years. These figures might vary considerably in a week's
2569 time, but in a year the record will come about right.

I consider that the records of cases in the City of St. Louis in regard to typhoid prove nothing except that all the cases were not recorded in the earlier years, and are not recorded now.

2571 Q. What is the amount of sewage that enters the Illinois River from Peoria?

2573 A. I don't know.

Q. Then, if you are not able to say whether it would or would not, can you say whether or not a typhoid bacillus on his journey from Chicago to St. Louis, coming in contact with the sewage-polluted water from the distilleries and glucose factories, would be able to live the journey?

A. I cannot say whether a specific typhoid bacillus would or would not be able to live under the circumstances assumed.

Q. Can you say whether a whole tourists' excursion of these bacilli would live or not?

2574 A. I think it entirely possible that some of them might squeeze through.

Q. Do you know of any one that has ever been able to prove that a typhoid bacillus that left Chicago ever arrived in St. Louis?

A. I think we have proved it in this case.

Q. Well, eliminating we, do you consider that you have proved it?

A. I don't know that I want to say that by my own individual self I have proven it, but I think it has been proven.

Q. Well, nobody knows any more about this subject than you do, do they?

A. Well, I don't think anybody knows very much more.

Q. And do you know it all?

A. No. I do not know how many distilleries empty their
2575 filth and sewage into the Illinios River at Peoria. But I don't see that it is of any importance whether there are one, 100 or 1,000.

Q. Have you ever been able to identify any bacilli of typhoid found in the Mississippi River above the intake as being indigenous to Chicago and not coming from the other towns located upon the water-shed of the Mississippi River above its intake, the Missouri or Illinois?

A. Certainly not; and it would be absolutely impossible to do so, any more than it would be possible to determine from what source a potato came that you might find floating in the river.

2576 A. Would the fact that you found a potato floating in the river prove that it came from Chicago?

A. Certainly not.

Q. If you are scientifically able to state that the sewage conditions existing in the Illinois River at Peoria do not kill the germs of typhoid or do not add to its longevity, and in the condition existing below Peoria on the Mississippi River where other germs may come from other places, how are you able to state that the typhoid germs will pass through the sewage polluted Illinois River at Peoria?

A. Because it is entirely possible that the typhoid germs might pass through the sewage polluted Illinois River at Peoria without coming in contact with the sewage from the distilleries and glucose factories that you have been discussing, if such exist.

2577 Q. Do you know that to be a fact?

A. Oh, I think that there is no question about it.

Q. Have you ever known of anyone catching lockjaw from drinking the germs of tetenus?

A. No, sir.

Q. Is it contended that people get it by taking it through the
2577 alimentary canal?

I believe not.

Q. Assuming that there should be typhoid fever in New Orleans, and two months before one case of typhoid fever appeared upon a steamer in Lake Itasca, the source of the Mississippi River, and there were no other cases of typhoid fever between that point and New Orleans, and no other source of infection, would you attribute the case in New Orleans to the case in Lake Itasca?

2578 A. I am afraid I would have to. These things do not generate of themselves.

Q. Now, in regard to this anthrax occurring in Chicago, did you ever hear of a case of anthrax in the City of Chicago?

A. I don't know that I have.

Q. Assuming that Chicago sewage would be cut off, what would you say about the conditions of the Mississippi River on the Missouri side to the people in Missouri drinking the waters of the Mississippi after it had received the sewage discharge of St. Louis?

A. I should say it would be unfit water for them to drink.

Q. Is there any more danger of hog cholera occuring in Chicago than in St. Louis?

A. I think that there is.

Q. Did you, when you dipped into the future, anticipate a cholera of hogs along the Missouri shore as due to Chicago?

A. It is entirely possible to get it.

Q. When you looked into the future and saw an impending calamity of cholera, did you really believe that such a thing was possible?

A. I certainly did, and certainly do.

Q. With the world's fair coming on and with people from all over the orient coming here, do you think that Chicago is more likely to get it than St. Louis?

A. That is only next year, and they all pass through Chicago anyway.

Q. You believe, then, that Chicago is more likely to get

2580 Asiatic cholera than St. Louis?

A. I do, yes, in the event of its coming to this country at all.

Q. Well, if it was prevalent here prior to the opening of the drainage canal, would you as a scientist who dips into the future attribute a subsequent epidemic to any contagion that might come from Chicago?

A. I shouldn't be inclined to attribute an epidemic from anthrax to Chicago upon its first appearance, but knowing the intimate relations which exist between Missouri or between Chicago and St. Louis, I could readily conceive that anthrax beginning in Mis-

2582 souri might travel to Chicago, infect the Chicago sewage and come back to Missouri with redoubled force as a result, and that the existence of such a possibility is an added menace to the health of the people of the State of Missouri.

RE-DIRECT EXAMINATION.

By General Crow.

Q. Well, then, the two cases in 1891 (at Port Huron) were
2583 not officially reported?

A. Well, they seem to have been accidentally reported by somebody.

2584-85 Further explanation for Port Huron Typhoid Conditions:

2602 ## GEORGE W. FULLER.

2603-04-05 Qualifications.

As a general proposition it is my judgment that the best index to the sanitary character of a public water-supply is the mortality record for water borne diseases in the communities using the
2608 water-supply in question, and especially the mortality statistics of typhoid fever.

It is my judgment that the water supplied to the citizens of St. Louis by the municipal water department during the years '95 to '99, inclusive, was what might be called a good sanitary water. I base that judgment upon this fact: During the period mentioned the typhoid fever mortality statistics show as low a rate, approximately speaking, as in the case of quite a number of other American cities having a pure or very nearly pure water supply.

It is my judgment that the raw Mississippi River water entering the intake tower during the period from from '95 to '99, inclusive, was a much less safe water from a sanitary standpoint than was the water after it had been treated in the settling basins and delivered to the consumers. This was due, of course, to the elimination of bacteria of an injurious nature by the process of sedimenation, and in which process the injurious bacteria subside, fall to the bottom of the basin, and from time to time are removed from the basin, and thus prevented from passing on with the water delivered to the consumers.

I would classify it in its sanitary character as a suspicious water, meaning by that not distinctively a good water, but one in which there was a liability of danger from time to time to those who drink it in its raw condition.

The average number of deaths from '95 to '99, inclusive, compared with the average number of deaths from 1900 to 1903 shows an increase of 80 per cent. There has been an increase during the last three years on the basis of 100,000 of population of about 60 per cent. Comparing the last three years with the prior five years
2611 an increase on the mortality percentage basis of 73 per cent.

Q. Mr. Fuller, I will get you to state, speaking broadly, what, in round numbers, considering all these methods, and all the facts, you consider the increase of typhoid in St. Louis to be in the period mentioned in the former question?

A. I should say in round numbers there has been an increase
2612 during the second period under consideration of about 60 to 70 per cent. above the average rate in the earlier period mentioned.

Q. Mr. Fuller, I will get you to state to what cause you ascribe the increased mortality of typhoid fever in the City of St. Louis from January, 1900, and why?

A. I ascribe it to an increased amount of infection in the public water-supply, and predicate this opinion upon the practically uniform distribution of the homes or residences in which the typhoid deaths have occurred in the City of St. Louis, and the further fact that a careful examination of the several other possible sources of typhoid fever shows that no substantial proportion of this increase may be explained in that way. * * *

I consider that the sanitary character of the public water-supply since January, 1900, delivered to the consumers in the City of St. Louis has been less safe than it was formerly.

In my judgment, it is the Chicago drainage canal discharged sewage, and drainage containing filth and infection from the City of Chicago, which makes the water in its raw condition at the
2614 intake tower chain of rocks, St. Louis waterworks, less safe than it was preceding January, 1900.

I estimate an increase of 60 per cent. in population sewering into the Mississippi River valley above St. Louis, due to the Chicago drainage canal. From Lockport to Grafton, a distance of 291 miles
2617 I place the rate of flow ordinarily at from ten to twenty-five days. It is my opinion that the average time required for the flow from Lockport to Grafton is about fifteen to eighteen days.

Q. Mr. Fuller, what, in your judgment, is the period of time which typhoid fever germs may and do continue to live in sewage polluted waters, such as are found in streams, reservoirs and the like?

A. I consider that they may and do continue to live for weeks and months under those conditions. * * *

Dilution at best does not destroy disease germs or infectious matter. Its effect is to minimize the danger to those who may drink of the water so diluted. One effect of the dilution existing in the Illinois River at low stages is to bring to Grafton more quickly than would otherwise be the case injurious matter entering the Illinois River at points along the route of its flow, and also entering the Illinois River from cities and towns located upon the tributaries of that river.

The most significant features of these so-called lakes and dams in slack water stretches is the low velocity of flow of water at times of low stages of the Illinois River. There are a good many days in the course of a year when these velocities of the places above referred to are so low that deposits take place to a considerable degree of the bacteria and other matters suspended in the water. * * * The resulting disturbances cause the bacteria to leave the bed of the stream in which they may rest for some time, bringing about the return of these bacteria to the flow of the water. In this way the germs of disease may pass from the Chicago drainage canal at Lockport to the mouth of the Illinois River at Grafton.

Q. Is it or is it not your opinion that typhoid fever germs, disappearing from the flowing stream and becoming deposited in the bed, are able to live there for weeks or months?

A. I think that they are able to live for weeks and months.

Q. Mr. Fuller, I will get you to state if, in your judgment, it is possible that water of the Illinois River, as it flows into the Mississippi, may sometimes be richer in typhoid fever germs derived from the Sanitary District of Chicago, and coming through the drainage canal, than was that portion of the water drawn from the drainage canal when it flowed over the bear-trap dam?

A. In my judgment, such a condition of affairs at times is not only possible but probable.

Q. Why?

A. Such a condition of affairs may arise, and at times probably does arise, through the disturbances of the sediment lying upon the bed of the streams in places which sometimes may, and undoubtedly at times does, contain relatively large numbers of typhoid fever germs. As these typhoid fever germs are returned to the flowing stream from their position in the bed of the river, there is affected an accumulated result whereby at times at least the waters of the Illinois River flowing to Grafton may discharge the concentrated essence of

the infection of Chicago sewage by taking in the manner above
2619-2620 described a portion of the infection coming from many days' flow of the drainage canal into the Illinois River.

I believe that these conditions (from Lockport to Grafton) are not sufficient to prevent at all times infectious material coming through the Chicago drainage canal and entering the Mississippi valley at Lockport from reaching the Mississippi River at Graf-
2621 ton. I believe the sewage from Chicago polluted the water of the Mississippi River along the Missouri shore, and renders it less safe for drinking and domestic purposes than it was before the opening of the drainage canal.

The typhoid conditions in Chicago since the opening of the drainage canal, in my opinion, did have an influence upon the ty-
2622 phoid fever death rate in the City of St. Louis, and that it is the cause of the principal portion of the increase during the past three years.

Q. MR. FULLER, I WILL GET YOU TO STATE, IF IN YOUR JUDGMENT THE INCREASED SEWAGE COMING INTO THE ILLINOIS RIVER BY WAY OF THE DRAINAGE CANAL AND THENCE INTO THE MISSISSIPPI, NOW AND IN THE FUTURE, WOULD ADD ANY DIFFICULTIES OR INCREASE ANY CAUSE TO THE PROBLEM OF FILTERING OR OTHERWISE PURIFYING THE WATER OF AND FURNISHING WITH SAFE WATER THE CITY OF ST. LOUIS?

A. In my judgment the increased amount of infection coming into the Mississippi River from the City of Chicago sewage at the present time makes an added responsibility as regards the treatment of that water to make it perfectly safe and wholesome as supplied to the citizens of St. Louis. Such treatment of the water would involve, I think, at the present time more responsibility, and in a financial way it would be shown by the greater expense of supervision of a filtration plant, and the added cost of supplies used in connection with the operation of filtration works, especially at times of low water. It would also mean that such filtration works, if adopted, would be operated from time to time, if not regularly, at lower rates of filtration than if this increased infection were absent.

The significance of this is that by reducing the rate of filtration that a larger plant would be required, and hence a more expensive installation of filtration works, to purify the same quantity of water than in the instance of water without this added infectious matter. * * *

There will ultimately come a time when single filtration can

hardly be expected to produce a satisfactory quantity of water with its source at the chain of rocks, intake tower. * * * Whatever the rate of flow may be in the communities situated upon the watershed of the Mississippi River above St. Louis, independent of the City of Chicago, it is certain that the added infection of the Mississippi River at the St. Louis intake tower to the Chicago sewage will hasten the day when single filtration at St. Louis will prove unsatisfactory, and when it will be necessary to give attention either to double filtration or to other methods involving increased expense and increased responsibility.

CROSS-EXAMINATION,

2624 By Judge Johns.

Q. Are there any times in the Illinois River or in the flow of the water from bear-trap dam to the intake at St. Louis when that water would free itself of infection if any infection existed in it?

A. There may be and may not be. I don't know. As to
2624 seasons, rate of flow and stage of river, I doubt it.

Q. You believe that infectious matter, flowing from the sewers in Chicago to the drainage canal, will certainly arrive at the St. Louis intake at times?

A. At times I certainly do.

If the City of St. Louis received its water-supply only from the Missouri, I think filtration would be desirable. It is not
2625 necessary in order to get a reasonably good water, as has been shown by its typhoid statistics and experience during '95 to '99.

Q. If the Illinois River and the City of Chicago did not exist, and the problem before the people of St. Louis now was, what to do with their water, do you think it ought to be treated?

A. In order to get a thoroughly satisfactory water, but, as I have stated, sedimentation from '95 to '99 gave them a reasonably hygienic water.

Q. Do you know whether or not sedimentation from '70 to '85 gave the City of St. Louis reasonably good water?

A. Judging from a sanitary standpoint, I should be inclined somewhat to doubt that. * * *

Q. Do you believe that typhoid bacilli, entering the drainage
2628 canal at Chicago, not only may be but are transmitted to the intake at St. Louis?

A. I do.

Q. Given a stream of water of 300,000 cubic feet a minute, into which the sewage of Chicago was poured, would there be any

length of time or any distance which would free that stream of typhoid infection?

A. By looking at it practically, I think it is very doubtful. Of course, I am not considering any distance which is absolutely impossible.

Q. If a stream of water of 300,000 cubic feet per minute, into which was poured the sewage of Chicago, was started in a tortuous course of a small river, at bear-rap dam, and received no dilution on the way, do you think it would purify itself by the time it reached New Orleans?

A. I do not believe that it would be absolutely free from infection. There would be a very great reduction there in the number of typhoid germs present.

Q. Do you not believe that there is any length of time or any conceivable distance for a stream of sewage to travel and in which time it will absolutely purify itself of infection?

A. Taking that as an absolute proposition, I think it is very doubtful.

Q. So that there is absolutely no such thing as the purification of a stream of running water into which infection was poured
2629 from sewage?

A. Absolutely speaking, I think that is very doubtful.

Q. If there were typhoid bacilli in the Missouri River and the water-supply of St. Louis was taken from the Missouri River, only there ought to be filtration or some treatment of that water?

A. I should advise it. The same for the Mississippi River.

2634 CROSS-EXAMINATION,

By Mr. Todd.

Q. What, in general, would be the added expense of such a plant covering the waters of the Illinois, the Mississippi and the Missouri over a plant filtering the waters of the Mississippi and the Missouri, taking the whole matter together? * * *

2637 A. It is a mere guess which I would give. Perhaps $20,000 or $25,000, for an off-hand opinion.

Q. Do you know as a matter of fact whether the conditions do not exist at the St. Louis intake, wherein the waters of the Missouri and the Mississippi are more infectious at times than the water from the Illinois?

2638 A. I do not know accurately about that. I think there may be some days in the course of a year when that might be possible.

Q. Do you think it is possible there are days during the course of a year when the water-supply of St. Louis comes exclusively from the Missouri River, and not from the Mississippi and Illinois?

A. No, I don't think that.

Q. Do you think there are days in the year when the water at the intake comes exclusively from the Missouri River and Mississippi, and not from the Illinois?

2639 A. No, I think that there is some Illinois River water at all times.

Q. When you look into the future, you have no pessimistic view about the growth of Kansas City, have you?

A. No, sir.

Q. With its near proximity to St. Louis in point of time, and the possibility of its getting typhoid contagion, is it not a danger and a menace present and impending to the water-supply of the City of St. Louis?

A. As a general proposition, I think it is.

Q. In considering the present, do you consider the waters of the Missouri River as a safe and usable water in their raw condition?

A. No, sir, I do not consider that the waters of the Missouri River at the present time is a fairly safe water.

Q. Would you consider a water such as the Missouri, with a town located within seven days of its water-supply, with the number of typhoid deaths as existed in Kansas City from '93 to '99, a safe water after it had been subjected to the conditions existing in St. Louis?

A. I don't think it would be absolutely safe, but practically
2642 speaking, I think it would be reasonably safe as judged by what was the actual experience in this city from '95 to '99.

Q. Assuming that you occupied the position of sanitary engineer in St. Louis, that there was no typhoid fever in the city, and that a plant such as the plant now installed here was just established, and that conditions existed along the Missouri River such as you are acquainted with as having been proven here, and the water-supply for the city was to be taken from the Missouri River, would you, as such sanitary engineer, recommend the water so treated as a safe water for drinking purposes?

A. I should probably recommend that they adopt filtration in connection with it, but if these funds were not available, and I was asked if sedimentation without filration would do for that water, and

whether it would be reasonably safe, or a good, decent water
2643 as water-supplies go in this country, I should say yes, that is my general view.

Q. During the years prior to 1899, do you consider that the sewage pumped into the Illinois and Michigan canal by the Bridgeport Pumping Works, and thence entering the Desplaines River, has an infected sewage?

A. I think that the sewage pumped into the Illinois and Michigan canal prior to 1899 contained infection in a considerable proportion,—in a large proportion, I may say, if the infection coming from the Chicago sewage remained on the Chicago side of the
2644 Bridgeport Pumping Station, where it was present with the sediment which remained undelivered by the pumps into that canal.

Q. If a considerable portion of that sewage was infected and once got into the Desplaines River, the typhoid infection would lie there in the sediment for a considerable portion of time, wouldn't it?

A. It might, but I don't think that infection would get into the Desplaines River to any large degree because of this septic action, which, OWING TO THE VERY NATURE OF THE PROCESS, MEANS A VERY TREMENDOUS GROWTH OF CERTAIN KINDS OF BACTERIA, THE ACTION OF WHICH IS KNOWN TO HAVE A DESTRUCTIVE INFLUENCE UPON THE GERMS OF TYPHOID FEVER.

Q. Do you think that the water in these settling basins (at St. Louis) has three whole days in which to settle?

A. No, I have stated it was less than that under the most favorable conditions.

2651 Q. Would it be an average of about a day and a half?

A. That would be a fair general figure, yes. * * *

On the Illinois River the typhoid germs and other bacteria which leave the flowing water and go to the bottom and lie upon the bed of the streams are subsequently flushed out by conditions which naturally occur on that bed and are returned to the flowing water and passed down towards the mouth, and some of them, many of them, doubtless do reach the mouth of the stream.

Q. How do you know that, Mr. Fuller?

A. It is a matter of common sense from the changing stages
2652 which occur in that river, the slope of the river and the various physical conditions which obtain there.

Q. Do you know how long a germ of typhoid fever would exist

in polluted water such as would come from the distilleries and glucose factories of Peoria?

2659 A. I should think some might live for several weeks or months.

Q. Have you any idea as to the volume of sewage that is emptied into the Illinois River from these factories and distilleries?

A. I know that the volume cannot be a very material one, for in examining the analytical evidence I have been unable to detect that is a controlling, or I might say a general or dominating,

2660 factor, taking this entire proposition of the disposal of Chicago sewage as it comes down through the Illinois River.

Q. Does the coli bacilli come from fish?

A. Why, in my judgment that is not very much of a practical proposition in these streams out here. I have based that on my experience, that in mountain streams where fish are very abundant there does not seem to be anything in the fecal discharges of fish to

2661 distort, in any very serious degree, the practical results to be derived from the colon test which I described. * * *

Q. In regard to the typhoid germ living in the sediment of streams, do you know of any one that has ever discovered a typhoid germ in the sediment of a running stream?

A. It has been found in the sediment of lakes, and we know of its existence beyond all doubt in the sediment of running streams.

Q. Has it ever been demonstrated by bacteriology that typhoid germs have lived in the sediment of running streams?

A. It has been demonstrated that they have lived for a long time in the sediment of lakes, and I do not consider that there is any weakness in the process of reasoning by which one steps from a lake to a river, provided, of course, that each of those waters are live waters, not subjected to septic action.

Q. By whom has it been ascertained that the typhoid germ has been found to live in the sediment of a running stream or a lake?

A. There are observers over in Switzerland who make such examinations with a positive result, showing the presence of typhoid germs in the sediment of Lake Geneva; I think also Lake Zurich.

Q. How long, after the germs were put into the sediment, was it before they were discovered?

A. I don't know in the case of the particular germ which

2662 were found, but they were found more than a mile from the shore or from the outlet of any sewers.

Q. Then the length of time that a typhoid bacillus will live in a sediment is more a matter of assumption than a matter of demonstrated proof?

A. I consider that it is a very clean-cut demonstrated fact that typhoid fever germs may, do, and have continued to live in the sediments of running waters.

Q. For what length of time?

A. I SHOULD SAY FOR A MONTH OR MORE, POSSIBLY IN CASES FOR YEARS.

Q. Who has demonstrated that it ever lived a year?

A. I think that the conditions existing in the MOIST SOIL in many rural places in this country where typhoid fever prevails from time to time are proof that typhoid fever germs, in the presence of moisture, can live for such a term. If that were not so, then
2663 there would be an elimination absolutely of typhoid fever through the rural districts of this and of other countries.

Q. Do you know of any specific instance where you have personally investigated and established beyond all reasonable doubt that a typhoid germ has lived for one year?

A. I am satisfied that beyond all reasonable doubt these typhoid fever germs which cause typhoid fever to prevail in isolated
2664 rural communities in many places in New England, with which I am familiar, and where I spent my boyhood days, that these germs most unquestionably did live in some instances for at least a year.

Q. How many years would you say that the typhoid fever germs in the instance that you have given has scientifically been demonstrated to have lived?

A. I will say several years. I will not go into detail beyond that. I think unquestionably they lived several years.

Q. Name me one man by name who holds that a typhoid germ will live for three years?

A. I think I am safe in stating Prof. Sedgwick.

2665 The prodigiosus bacillus was found in the Ohio River at Cincinnati on one occasion.

RE-DIRECT EXAMINATION

2666 By Gen. Crow

I will further state that in the instance of the waterworks plant in the City of Covington, Kentucky, the source of this water-supply is the Ohio River. There are provided sedimentation basins holding approximately thirty days' supply. It has been found that
2667 year after year the citizens of Covington using the Ohio River water coming from these basins are not protected from typhoid fever.

There is documentary evidence to the effect, and there is also practical observation as to the amount of scouring which must take place (in the Illinois River). As to the former, I will state that it is not recorded in the report of the Chief of Engineers of the United States Army; that the engineers in charge of the Illinois River found that where channels are dredged in that river they are nearly permanent. "Channels dredged twenty years ago are but little de-
2668 teriorated, and it is surprising to find that there has been no deterioration in depth in the pools created by the Henry and Copperas Creek dams after from fifeen to twenty years ago."

2671 WILLIAM H. GETZ.

2672 Table of percentages of Missouri and Mississippi River water at the intake of the St. Louis waterworks.

2688 HIRAM R. MILLS,

Practicing Physician of Port Huron.

Q. Do you know of any cases (of typhoid fever) in the summer and autumn of 1891 in Port Huron?

A. Yes, sir.

2689 Q. Of how many cases did you have personal knowledge?

A. In 1891 there were four cases, I looked up.

CROSS-EXAMINATION,

By Judge Johns.

There were four in 1890. Otis Scott, corner Broad and Ontario streets, June and July. He lived.

I understood that at the time it (the house) was connected with sewers, but I couldn't say positively that it was, because I didn't make the examination to trace it up and see. I told the nurse as to what to do with the dejecta. She was to use disinfectants and put it into the closet. I think their closet was connected with the sewer.

Q. It was disinfected by what means or what process?

2692 A. The use of carbolic acid or copperas, and sometimes put into boiling hot water.

MRS. BUNCE,

Lepia Avenue, near Ninth Street.

I don't know whether it (the house) was connected with the sewer at that time or not. It seems instructions about disinfectants were given.

FRED GOODING,

Ontario Street, near Pine Grove Avenue, in September and October.

I think the house was connected with the sewer. I am not sure about that, either.

Q. You are not certain that their house was connected with the sewer?

2693 A. No, sir.

Same instructions about disinfectants.

Q. Do you know whether the dejecta from that patient, when it was disinfected, went into the sewer?

A. I couldn't say positively that it did.

The next was Massmore on Lepear avenue, in October and November.

Q. You gave the usual orders as to the dejecta disinfected?

A. Yes, sir.

Q. Do you know whether dejecta, whether disinfected or not, went into the sewer?

A. I don't know that it did, but I suppose it did.

Q. You had no positive knowledge on that?

A. No, sir.

In 1891 Mrs. John Folkers, Miller street, in August. No

2694 sewer there.

Q. Now, you gave the usual order there to have the sewer disinfected?

A. Yes, sir.

Q. But do you have any positive knowledge in regard to dis-

2695 infecting the sewage or the dejecta of these patients?

A. No, sir, I have not.

Q. Do you know?

A. I don't know whether they attempted it or not. I told them to do it. I gave them the instructions. Now, whether they did it or not I cannot say.

Q. Now, you have absolutely no knowledge on that subject?

A. No, sir.

In October, 1891, another case in the same family. They lived on Quay street, that is right on the bank of Black River.

Q. Was it connected with a sewer in this house?

A. No, sir.

Q. Do you know whether that dejecta was disinfected or not?

A. I do not.

Q. Did you give orders to have it disinfected?

A. Yes, sir.

The next: A. H. Mayer, in April and May, Gillette street, 2710 between Twelfth and Thirteenth.

Q. You left directions with the nurses in all these cases for the disinfection of the dejecta?

A. Yes, sir.

Q. You also left directions with them as to how to attend to the patient?

A. Yes, sir.

Q. And you found that in matters that came directly under your observations these nurses carried out your instructions?

A. Yes, sir.

Q. And there is no reason to assume that they did not carry out your instructions?

A. No, sir, I have no reason to believe they did not.

Q. In regard to disinfecting the dejecta?

A. The only thing is, I know that oftentimes they get care- 2711 less about some things, but that is outside of my knowledge. I don't know whether they did or not.

CHARLES B. STOCKWELL,

a physician in Port Huron.

From personal knowledge I have a record of three cases of typhoid in 1892.

Q. What month of 1892 was that?

A. February, March and April. One of these cases extended into May, beginning in April—April 3d.

Q. Do you know whether or not any of the houses in which these patients were sick had a connection with the drainage, directly or indirectly, in the Black River?

A. In two of these cases. In one case I know there was direct connection with the Black River by private sewer, and in another one there was direct connection with the ST. CLAIR RIVER, but not

direct connection either—I believe it was by one of the sewers. I don't know, either.*

The mouth of the sewer from the house which drained into
2716 St. Clair River was a little over half a mile above the Black River.

In regard to the second patients, whether the sewage went into Indiana Creek, I would not be certain. I know it was on the bank of a stream, but what was done with it I don't know.

Q. Now, the third case in 1892, where was it?

A. The other was—it was within 200 feet of Black River, just above what is called Seventh street bridge. It was connected with a private sewer.

Q. Now, do you know whether the discharges of that patient were disinfected?

2717-18 A. I think they were not. I don't remember of ever telling them. They were just simply taken immediately to the closet and flushed out.

OLIVER STEWART,

Physician, at Port Huron.

Q. How many cases of typhoid fever do you know of during the years 1889, '90 and '91?

A. In 1889 I had five cases. In August I had three cases.

Q. August, 1889?

A. In August, 1889. I had one in September and I had one that ran through between October and November. It was principally in these two months.

Q. Now, what did you have in 1890?

A. I had five cases in 1890. I had four in one house in September running into October, in 1890, and I had one case on Ninth street between Howard street and Pine. That was in September.

Q. How many cases did you have in 1891?

A. I had four. I had one in September that ran into Octo-
2720 ber. Then in October I had three other cases, one of them being a tramp, at the hospital.

Q. Now, did any of the patients or the houses in which they were located have any sewer connections?

A. One I know did, but I am not positive of any of the rest. Yes, there are two. Now, just wait a minute. That last one I am

* Of these three cases only two could possibly have direct connection with the Black River where the dredging is alleged to have taken place.

not so sure about that. I fancy that one did, but when I think
2721 of it I cannot say positively that that one did have any sewer connection. Then there was one on Thirteenth street. I don't think there were any sewers there at that time.

Q. Now in 1891, four cases, who were they?

A. One was a boy about nineteen on Thirteenth and Miller streets. The same instructions were given them. I think they were carried out. His mother took care of him, and she was both industrious and faithful.

Q. And the other three?

A. This one, a girl on the corner of Leapyear and Eleventh streets. I am very certain was, because her mother took care of her. They were a very intelligent family, and I believe they followed instructions.

Q. Now then, this third case?

A. That one, her mother took care of her, and I think I can say the same thing for her.

Q. And the fourth one?

2724 A. That was the tramp in the hospital.

FRANK F. ROGERS,

2729 Civil Engineer.

I think there was a little dredging done in the fall of 1891.
2732 The principal dredging in 1892.

Q. What time in 1892 did the dredging commence in the Black River?

A. It began in April.

Q. What day in April?

2734 A. I couldn't give it to you, sir. I have not looked it up recently.

It began in April and continued during the season. It may
2741 have been stopped at brief intervals, but not for long. I would have no means of knowing just what days or just what times dredging was going on.

2745 E. J. HAYNES,

U. S. Engineers' Office, Detroit.

Q. When did you begin the work in 1891?

A. That would be about November—about the 1st of November.

Q. How long did you work there in that fall?

A. I went away on Thanksgiving day, about the 25th. Somewhere between the 25th and 27th.

Q. Now, was there any work done in the Spring of 1892, dredging at Port Huron and the Black River?

A. Yes, sir.

Q. What was it and how long did it last?

A. I couldn't say just how long it lasted. I went there along the middle of April. I was there for something like two or three months.

2747 Q. Do you know how much was taken out in April, '92?

A. About 5,200 yards.

2747 CROSS-EXAMINATION,

By Judge Johns.

Q. What was the current of the river, the Black River?

A. During the summer months there was no current. In the
2756 spring there was a freshet which took the ice and everything out of it.

2758 WILLIAM T. SEDGWICK,

Recalled concerning Washington Episode.

Q. What other stream is it that you have investigated and found the waters polluted?

A. I have visited Washington and made a careful examination of the typhoid fever statistics on file in the office of the Department of Health, and in particular have inquired into a very serious and extensive infection of the river, which took place at Cumberland, Maryland, in 1890. I have also visited Cumberland and have made inquiries from some of the physicians, and have secured by correspondence from one of the physicians who at the time of the epidemic wrote about it, * * * and I find that in December, 1889, and more particularly in January, February, March and April, 1890, there was * * * in the City of Cumberland a very extensive epidemic of typhoid fever, the effect of which was at the time by a competent investigator asserted to be plainly discoverable in an increase of typhoid fever cases in Washington. I have recently reviewed the records in Washington and obtained from physicians on the spot at the time in Cumberland the facts so far as they could give them to me in that city, and I believe that this epidemic and its

CONSEQUENCES contribute one of the most important examples on record of the transmission of typhoid fever germs from long distances. * * * There appear to have been in

January, 1890,	18 deaths.
February,	27
March,	39
April,	8
May,	5

and there was also one death in December, but this was that of an imported case. * * * There were therefore, all told, in the 2,759 epidemic in Cumberland, 98 deaths from typhoid fever, and although it has been repeatedly stated in sanitary discussions and pamphlets relating to the water-supply of Washington that there were 485 reported cases of typhoid fever in Cumberland at this time, and in this epidemic, the number of deaths indicates that there must have been actually nearly double that amount. AN EFFECT OF THIS EPIDEMIC APPEARS TO HAVE BECOME MARKED IN WASHINGTON IN MARCH, 1890, WHEN THE TOTAL number of deaths from typhoid fever was 19, and to have existed through August, the number of deaths per month (in Washington) having been: March, 19; April, 11; May, 13; June, 33; July, 36; August, 28, and after August no effect of the epidemic can be traced in the deaths from typhoid fever in Washington. This case is a particularly interesting one, and has been repeatedly referred to in public meetings and conferences and hearings before congressional and other committees and the like in Washington, but has not hitherto found its way to any considerable extent into the books upon the subject. I regard it, however, as perhaps upon the whole, as I have already indicated, a most instructive example of the transmission of typhoid germs in a polluted stream from a long distance, because Cumberland is about 175 miles from Washington by the river, and because the river is of such a character as to offer a good example of a stream, neither very swift nor very slow, but having occasional areas of what might
2760 be called slack water; these succeeded by steeper portions, and therefore affording good opportunities for a certain amount of so-called self-purification en route.

One other fact of great importance I think should be mentioned. Between October 4th, 1899, and March 18th, 1890, the sedimentation basins in Washington and the distributing reservoirs also appear to have been out of service, so that during this period the water of the Potomac was delivered to the citizens of Washington without purification of any kind; a fact which no doubt added to the severity of the

outbreak in Washington. * * * The typhoid deaths, the excess of typhoid deaths; Washington has long had an extensive death rate from typhoid fever. This has been attributed in part by com-
2761 petent experts to the use in that city of the Potomac River water for drinking purposes, but during and from March, 1890, through August of the same year, this excess reached extraordinary proportions, so much so that if the typhoid deaths for the years previous to 1890 are compared with the average typhoid mortality for the years previous to 1890 and for the five years after 1890, it appears that this excess amounted to about 100 per cent. That is to say, in addition to the ordinarily excessive typhoid of Washington, there was apparently, owing to this epidemic in Cumberland, Maryland, a further excess of about 100 per cent. So clear was this connection regarded or held to be by local authorities, THAT WHEN A CASE OF ASIATIC CHOLERA WAS REPORTED TO HAVE APPEARED IN CUMBERLAND, MARYLAND, IN 1894, GRAVE ANXIETY WAS FELT BY THESE EXPERTS IN WASHINGTON. Fortunately, however, the case proved to be something else than Asiatic cholera. The question will naturally be asked, how long does it take for water to flow from Cumberland to Washington, and this time has been variously estimated, but, as given by Captain Gaylord, of United States Engineers, in Senate Document No. 94, Fifty-fifth Congressional, second session, as from four to seven days from Cumberland to the intake, and by one of the officials from the United States Geological Survey as from two to four days. It is interesting to note in connection with the epidemic in Washington in 1890, which followed that in Cumberland, Maryland, in the same year, that the excess of deaths from typhoid fever in Washington is not clearly marked until two months after the outbreak in Cumberland. That is to say, while there were eighteen deaths in Cumberland in January, 1890, no marked excess appears in Washington until March. Furthermore, while the epidemic in Cumberland ended in May, that in Washington was continued vigorously during July, and even to some extent during August. WHETHER THIS DELAY IN THE INSTANCE OF DEATHS IN WASHINGTON IS OR IS NOT DUE TO THE TEMPORARY DEPOSIT OF THE GERMS IN THE BED OF THE STREAM, FROM WHICH THEY WERE AFTERWARDS RETURNED FROM THE FLOWING WATER AND DELIVERED TO WASHINGTON, IT IS IMPOSSIBLE TO SAY POSITIVELY, BUT IT IS DIFFICULT TO RESIST THE

FEELING THAT THIS MAY HAVE BEEN THE CASE.

2762 Cumberland at that time was 12,000 in population.

The population of Washington was 25,000.

2763 Q. Do you know how the distance from Cumberland to Washington by river compares with the length of the river

2764 Thames, in the United Kingdom?

A. The Thames is 200 miles long, and is I believe, the longest river in the United Kingdom, and this epidemic seems to confirm in a very remarkable way that statement of the RIVER'S POLLUTION COMMISSION OF GREAT BRITAIN, TO WHICH I HAVE REFERRED IN MY PREVIOUS TESTIMONY, WHERE THEY STATED THAT THERE WAS NO RIVER IN THE WORLD THAT WAS LONG ENOUGH TO PURIFY ITSELF OF ANY SEWAGE INTRODUCED INTO IT, EVEN AT ITS SOURCE.

Q. This record you have here, is that an official report of the commissioner?

A. This is the official annual report of the Commissioners of the District of Columbia, so far as the Department of Health is concerned. * * *

In 1895 there was another serious epidemic in Washington,

2765 which was carefully investigated, but it was not directly connected, so far as I am aware, with the events of typhoid fever in Cumberland.

Q. Now, from your knowledge of the situation and of the conditions that prevailed in '89 and '90 in the City of Cumberland, Maryland, and the City of Washington, the conditons of the Potomac River and the water supply of the two towns of the sewage and human deffication of the stream of the Potomac River, I will get you to state whether or not, in your judgment, the epidemic of typhoid fever in 1889 and 1890 in the City of Washington was caused by the placing of sewage infected with typhoid bacilli in the waters of the Potomac River at the City of Cumberland, Maryland?

A. I should hardly call the excess of typhoid fever in Washington in 1890 an epidemic, although that term might perhaps very well be applied to it. It was rather an extraordinary and unusual excess of typhoid fever, and, in MY JUDGMENT, THIS EXCESS WAS AND IS DIRECTLY TRACEABLE TO THE GREAT EPIDEMIC OF TYPHOID FEVER OCCURRING SHORTLY BEFORE AND DURING A PORTION OF THE SAME PERIOD IN THE CITY OF CUMBERLAND, MARYLAND,—germs from that

epidemic having apparently passed down the river into the
2766 water supply of the City of Washington alive and virulent. Of course, there must have been a considerable removal of germs en route, else the outbreak in Washington would have been far more severe.

2767 CROSS-EXAMINATION,

By Judge Johns.

You are now acting for and in behalf of the State of Mis-
2767 souri in an advisory capacity in this lawsuit, as an expert?

Q. What other experts have studied the epidemic at Cumberland and the consequent increase of typhoid at Washington in '90 and '91?

A. So far as I know, no one has studied it thoroughly, excepting Dr. Kober, and, if I may be permitted to say so, myself.

Q. What other experts had grave apprehension as to Asiatic cholera when it was discovered that there was a case of Asiatic cholera in Cumberland?

A. My authority for the statement which I have made in that connection is Dr. J. J. Kenyoun. * * * until recently connected with United States Marine Hospital Service, and it is found
2769 in a discussion by Dr. Kober of the question of water supply for the District of Columbia published in Document 183, Fifty-fifth Congressional, second session, page 25.

Q. What other authorities, now, had grave anxiety about Asiatic cholera than the one you have named?

A. He is the only one that I know of who had such anxiety, but, as I know that he was associated with other sanitarians of knowledge, I have no doubt that the matter was talked over at the time.

Q. Did you talk with Dr. Kober yourself, in this visit to Washington?

A. No, sir; I did not.

Q. Your information as to his grave anxiety arises from reading something that he got in print?

A. It does.

Q. Then, because he did that you infer that other sanitarians had like grave anxiety with reference to it?

A. I do.

Q. Now, before what committee of Congress was this epidemic in Cumberland discussed?

A. It was not discussed, so far as I knew, by any committee.

Q. By what committee was it investigated?

A. Nor was it investigated. * * *

2770 Q. Now, whether any committee of Congress actually investigated the epidemic in Cumberland you are not prepared to state?

A. I am not prepared to state.

Q. Now, from what source did you obtain that information

2771 of 485 cases in Cumberland?

A. That rests both in Dr. Kober's reports and in my own case upon the authority of Dr. W. W. Wiley, of Cumberland. The health records of Cumberland are extensively defective. * *

2772 * and I am dependent, as Dr. Kober was, upon Dr. Wiley, the local physician.

Q. What is the area of the fall of the Potomac?

A. I have no personal knowledge of this, but, referring to Colonel Miller, of the United States Engineers, the drainage area above the intake figures 11,043 square miles.

Q. Forty-four and one-half of population to the square mile?

2774 A. Yes, estimated for 1890.

Q. Now, in 1889 was typhoid fever in any one of these towns save Cumberland?

A. Not so far as I have been able to learn.

Q. You have not heard of any?

A. I have inquired and have not learned of any.

Q. What kind of inquiries did you make about it?

A. In Washington, talking with health officials who are fairly familiar with the water shed, and in Cumberland with physicians.

* * *

Q. With what other persons have you talked upon the subject?

A. No other persons in Washington, except some other people in the office whom I didn't know, but in Cumberland, with the doctors that I referred to.

Q. You arirved there (at Cumberland) on some morning train

2775 and left on some noon train?

A. The other way. I arrived at noon and left at night.

Q. Do you know whether there was typhoid fever in any of the towns on any of the tributaries above Cumberland, on the Potomac, at that time?

A. Not so far as I could learn.

2776 Q. You have not heard of any?

A. I have not heard of any.

Q. Was there any typhoid in this period and prior to it in the falls of that river?

A. I don't know of any, but I have no doubt there was some few cases.

Q. Having learned from reports and conferences that there was typhoid fever at Cumberland at one time and subsequently a remarkable increase of typhoid fever in Washington, and not knowing as to typhoid fever at any place else, you conclude that the typhoid fever in Washington is attributable to Cumberland?

A. I do.

Q. Your entire knowledge of it has been gained and acquired since about the 1st of June and since that time?

A. My DEFINITE knowledge of it has been acquired since that time. * * *

Q. Can you tell me why the cases in January, 1890, in Cumberland didn't show any effect, if they ever had any, in Washington in February?

A. I cannot. There was a slight increase in January in Washington, but it was so slight that I didn't feel it fair to attribute
2777 it with any strong presumption or probability to the cases of Cumberland. * * * At the same time it is entirely possible that this slight excess in January was due to the cases in Cumberland.

Q. At what time is the Potomac River in flood at Cumberland?

A. I have not learned with any great degree of accuracy of the flood periods of the Potomac, or at least from the statement of Captain Gaillard, that its flow is very marked, varying from a minimum of great falls of about 1,063 feet per second, to between 400,000 and 500,000 during the great freshet in June, 1889. * * *

Q. And do you know when there was another flood after that?

A. I do not.

Q. Or in the winter of 1899 and '90?

A. I do not; but, of course, it was fair to suppose that with the breaking up of the snow on the Virginia mountains and the Allegheny there must have been the usual spring floods. I HAVE NOT UNDERTAKEN TO CONNECT CLOSELY THE TYPHOID IN WASHINGTON WITH THE TYPHOID IN CUMBERLAND, BELIEVING THAT NO SUCH CLOSE CONNECTION COULD BE TRACED TO THAT, BUT THAT ONLY A BROAD AND GENERAL CONNECTION WAS DISCOVERABLE.

Q. Do you believe that the typhoid fever which occurred in
2779 Cumberland in January, 1890, contributed to the typhoid fever in Washington in March of the same year?

A. I certainly do.

Q. On what theory?

A. For the reason that we have good reason to believe that germs of that disease were deposited in the Potomac River water at Cumberland. We know that this water travels down the river, and is, in part at least, used for drinking purposes by the people of Washington. We find an otherwise inexplicable excess in typhoid fever in Washington at a time following when such increase would reasonably be unexpected.

Q. All the water in the Potomac River at Cumberland had flowed past the City of Washington in the Potomac water long before this epidemic or increase of typhoid fever in Washington, that is to say, the water infected, if it was infected, by typhoid fever in January at Cumberland, had flowed past the City of Washington, a very considerable time before, allowing for the period of incubation, had it not?

A. I should suppose that it must have, in a large part, perhaps entirely. * * * I think we should bear in mind that in January it is possible that the stream was tightly frozen and that sedimentation took place to an unusual extent for a time.

Q. Is the Potomac River ever frozen between Cumberland and Washington?

A. I have no personal knowledge of it, but I don't see how it can be otherwise. * * *

Q. Of course, there is no way of determining as an actual fact whether any typhoid fever germs were deposited in any of the
2779 sluggish places in the Potomac River?

A. No, sir.

Q. Nor whether they were washed out so as to contribute to the typhoid fever in Washington in March?

A. No, sir. We can only infer from the end results what may happen.

Q. And the belief that typhoid fever in Cumberland was the cause of typhoid fever is based upon the theory that typhoid
2780 fever germs live in water and are transmitted by water and retain their virulence?

A. That certainly is the theory stated.

CROSS-EXAMINATION,

2780 By Mr. Todd.

Q. What percentage of the sewage of Cumberland found its way into the Potomac River?

A. That would be impossible for me to answer, or for any
2780 one else to answer.

I have no information as to the number of typhoid cases or deaths that occurred in houses where the out-houses overhung the stream, nor as to the number of typhoid deaths that were in
2782 houses that used private vaults.

Q. Have you any information as to whether the fecal discharge from typhoid patients in Cumberland was treated by the application of any antiseptic?

A. I have not.

Q. If it should appear that under the direction of the doctors such antiseptic precautions had been taken, would not you deem it necessary to ascertain that fact in order to draw a correct conclusion as to the effect of the sewage of Cumberland upon the Potomac River?

A. No, sir; I should not, broadly speaking, because it is well known that any such general order for disinfectants or any such practice of disinfectant is always only partially obeyed, and I
2783 should rather believe that the moderate character of the excess in Washington, which I have hesitated to call an epidemic, was, in part, due very likely to some such disinfection.

Q. Do you know whether the out-houses that received the
2784 excreta of the typhoid patients were emptied into the Potomac or not ?

A. I do not.

Q. Did you make any inquiries from anybody at Harpers Ferry who would be most likely to know the (typhoid) conditions there?

A. I did not.

Q. Did you make any inquiries especially as to whether there
2786 was any typhoid fever at Harpers Ferry or not from any one that lived at Harpers Ferry?

A. I did not. * * * I made no inquiries except of the health authorities in Washington and Cumberland.

Q. Do you know whether he (the health officer) made any investigation at Harpers Ferry to ascertain the condition that existed there at this time?

A. I do not.

Q. And whether typhoid fever existed at Harpers Ferry at
2787 this time or not, you have no knowledge, professor?

A. I have no personal knowledge.

Q. Do you know how many cases of typhoid existed between Cumberland and Washington along the water shed of the Potomac?

A. I do not.

Q. Did you make any investigation to ascertain the number?

A. No, sir. * * *

Q. And the reason that you didn't do it was because you didn't deem it essential?

A. That's it exactly.

Q. And whether there were a great number of typhoids there or not you are not prepared to say, are you?

A. I am not prepared to say positively, but if there had been I am sure that I should have heard of it.

Q. If you made no effort to ascertain it, how would you have heard it?

A. Because Dr. Kober, who investigated the thing at the time, would have been, in my judgment, sure to mention the fact, as he is a careful man.

Q. Then, the fact that no one mentioned it to you is the only ground that you have for believing that there was any considerable amount of typhoid fever within that stretch of 170 miles?

A. Not exactly that no one mentioned it to me, but that no record of it appears in the report of the investigation at that
2788–89 time.

Q. You made no effort to ascertain that fact, did you?

A. No, I did not. I didn't deem it necessary.

ALLEN HAZEN.

2789 Q. Did you secure any data as to typhoid deaths in St. Louis on this investigation?

A. Yes, I got the deaths as reported at the health office. I made no detailed investigation of the methods of securing and
2798 recording that data.

Q. Mr. Hazen, I will ask you what has been the effect, if any, in your opinion, of the discharge of the waters of the Chicago Drainage Canal carrying the sewage of the Chicago Sanitary District into the DesPlaines River under conditions existing since January 19, 1900, upon the water of the Mississippi River along the Missouri shore, and particularly as shown from the intake tower of the water-

works at the chain of rocks, with reference to its use for drink-
2799 ing and domestic purposes?

A. I believe that the quality of the water is seriously damaged by this discharge.

Q. Now, are you familiar with the stream flow in the canal and the DesPlaines and the Illinois and the Mississippi rivers in a general way?

A. In a general way; yes, sir.

Q. Are you familiar in a general way with the stream flow
2800 and velocity of the Missouri and Mississippi rivers, both?

A. Yes, sir.

Q. In a general way, do you know about the time of flow, what it would be from the City of Chicago, through the canal, the Des Plaines River, the Illinois and the Mississippi rivers, to the intake of the water-works at St. Louis?

A. I have seen estimates of that. I have no data of my own to compute it.

Q. Now, this opinion that you have given as to the effect of the Chicago Drainage Canal upon the waters of the Mississippi River at the intake,—what was that based upon?

A. It was based upon the facts that the sewage entering the water-course above the intake was nearly doubled, by this discharge; that the distance from Chicago to St. Louis is very considerably less than the average distance of the other points of dilution from the St. Louis intake; that the mixing of the waters in the channel of the Mississippi River is such that the amount of sewage received at the intake is a large part of what it would be if the mixing were complete, and that the times of passage from the point of pollution to the intake were not sufficient to allow the complete destruction of the injurious and polluting matters discharged.

Q. I will get you to state, if you know of your own knowledge, whether or not the waters of the Mississippi and the Missouri and the Illinois rivers commingle at the intake of the St. Louis water-works?

A. They do.

Q. I will get you to state whether or not you know of your own knowledge if the waters of the Illinois River or some portion
2801 thereof pass into the intake of the St. Louis water-works?

A. Yes, sir.

Q. Now, in view of these matters, I want to repeat the same question I put to you before: Now, I will just repeat the same question: What has been the effect, if any, in your opinion, of the dis-

charge of the waters in the Chicago Drainage Canal carrying the sewage of the Chicago Sanitary District into the DesPlaines River under the conditions existing since January 19, 1900, upon the water of the Mississippi River along the Missouri shore, and particularly as drawn from the intake tower of the St. Louis water-works at the chain of rocks with reference to its use for drinking and domestic purposes?

A. It seriously injures the quality of the water.

2802 CROSS-EXAMINATION,

By General Hamlin.

I made a report upon the water supply of St. Louis.

Q. What was your report?

A. I recommended the continuance of the Mississippi water-
2803 with filtration.

I could give you an approximate idea of it (cost of filtration). It is about $2,000,000 for a filtration plant proper, $700,000 or $800,000 for auxiliary work which would be necessary in connection with it. It was something under $3,000,000 for the whole project, as required by the present requirements of the city. * * *

Q. Have you ever made any chemical analyses of the water of St. Louis?

A. No, sir.

2804 Q. Have you ever made any bacteriological examination of it?

A. No, sir.

Q. Now, you take the pollution at St. Louis, you made no chemical analyses of the water at St. Louis?

2805 A. No, sir; it was not necessary.

Q. Nor did you make any bacteriological examination?

A. No, sir.

Q. So, based upon either of those, you have no knowledge at
2806 all other than what you get from some other source, have you?

A. No, sir.

Q. Have you ever traveled from the Drainage Canal and down the Illinois River and the Mississippi to St. Louis?

A. Not over the whole distance; no, sir.

Q. You have been as far as Joliet and LaSalle?

A. Yes, sir.

2807 Q. Not now?

A. No, sir.

Q. You are of the opinion, then, as I believe you stated in your report, that there should be filtration at St. Louis?

2807 A. Yes, sir.

Q. Well, then, would it cost any more to establish filtration plants, suppose that you eliminate the Illinois River, and put in the Missouri and the Mississippi River?

A. It would make no substantial difference.

CROSS-EXAMINATION,

2809 By Mr. Todd.

I examined the plants of the water-works at Kansas City, Kansas; Kansas City, Missouri; St. Joseph and Omaha to find out the character of the Missouri water and the methods which were necessary to treat it, and the results which could be secured by those methods. I assumed that the sewage from Omaha, Kansas City, Kansas; Kansas City, Missouri; Jefferson City, emptied into the Missouri River.

Q. And what effect did you assume this sewage to have upon the water, the quality of the water of the Missouri River, before it emptied into the Mississippi?

A. It changed its quality.

Q. Did you consider it a safe and potable water?

A. No, sir.

Q. Do you consider it so now?

A. No, sir.

Q. A safe and potable water?

A. No, sir.

Q. If the Illinois River could be dammed at its mouth, and a channel cut whereby it could empty below the intake tower of the City of St. Louis, would you consider the water of the Missouri and Mississippi which enter the intake tower at St. Louis a safe and potable drinking water?

A. No, sir.

Q. Assuming that a channel cut from the Illinois River should empty into the Ohio River at Cairo, thus eliminating entirely the Illinois River water from the Mississippi between Cairo and Grafton, would you consider the water of the Mississippi at Cairo a safe

2811 and potable drinking water?

A. No, sir.

Q. Mr. Hazen, if you were to venture an opinion as to the character of the Mississippi River water above Cairo, would you consider

that its character was made unwholesome and unpotable by the sewage discharged into the Mississippi River by the cities in Missouri emptying their sewage into the Mississippi River, as well as the cities on the Missouri, emptying their sewage into the Missouri River?

A. I think that the discharge renders the water less wholesome and less potable. I cannot say that it renders it unwholesome and unpotable, because it may be that it would be unwholesome and unpotable without them.

Q. Assume that the waters of the Mississippi above its confluence with the Missouri were unpolluted streams, and assume that the sewage discharged into these rivers by the cities in Missouri, such as Kansas City, Missouri; Jefferson City, St. Charles and St. Louis, and the other smaller towns that empty their sewage into these rivers, would you consider the water of the Mississippi River above
2813 Cairo a safe and potable water?

A. I should not, off-hand. It is a question that I have not studied in detail.

Q. Would you consider the water of the Mississippi River above Cairo, under the conditions existing in the hypothetical question, but with the additional information as to the rate of current and time of flow in the Missouri River and the Mississippi River, a reasonably safe drinking water after it had received the addition of the sewage from these different cities in Missouri?

A. I think not.

Q. Mr. Hazen, assume that in the southeast corner of the State of Missouri a company was about to establish a large city, and conditions existing along the Mississippi River above that point were such as are contained in the hypothetical question, and you should be selected as the sanitary engineer to look out for its water supply, knowing the conditions as I have assumed them in the hypothetical question, and before you could ascertain whether this water was going to kill anybody or not, what would you say as to whether the waters of the Mississippi, under these conditions, would be a safe drinking water for the future inhabitants of this supposed city, not being artificially treated?

A. I think not.

Q. That is, you wouldn't consider that water a safe drinking water?

A. No, sir.

Q. Assume that the Illinois River should be diverted to Cairo in the manner I have indicated and knowing all the conditions that obtain upon the upper watershed of the Mississippi and the Missouri

Rivers, as they do to-day, and the water system in St. Louis, as it now exists, would you consider that water a safe drinking water for the people of St. Louis?

A. I should not.

2815 Q. Then the cities bordering upon the Illinois River and the conditions that obtained prior to January 19, 1900, would not make the water supply of St. Louis a safe and usable water supply under existing conditions, in your judgment, would it?

A. No.

2816 Q. After the waters have left the controlling works at Lockport do you know how far they flow before they enter the Illinois River.

A. No, sir.

Q. Now, have you ever investigated the conditions that obtain in what is known as Lake Joliet?

A. No, sir.

Q. Do you know whether there is such a thing as scouring 2826 that takes place in Lake Joliet?

A. No, sir.

Q. Do you know how many dams are located in the Illinois River from La Salle to Grafton?

A. I have seen records of it. I don't know it from personal knowledge.

Q. How far from the dams is the effect of those dams experienced by the waters of the Illinois River up stream?

A. I could not say.

2827 Q. Have you any opinion as to what amount of deposit has been made in the Illinois River above the dams?

A. No, sir.

Q. Do you understand what period of the year the Illinois River flows between its natural banks?

A. No, sir.

Q. Have you any idea how many acres of land in the valley of the Illinois is overflowed throughout the year by the Illinois River?

A. No, sir.

Q. Do you know how far Peoria is from La Salle?

A. I don't recollect, no, sir.

Q. Are you acquainted with the size and dimensions of what is known as Lake Peoria immediately above Peoria?

A. No, sir.

Q. Do you know what the condition of the water immediately above Peoria was prior to the opening of the drainage canal?

A. No, sir.

Q. Do you know what its condition is since?

A. No, sir.

Q. Do you know whether the water of the Illinois River above Peoria is less polluted to-day than it was prior to the opening of the drainage canal?

A. No, sir.

2830 Q. Have you any idea of the number of cattle that are fed along the banks of the Illinois River by the distilleries?

A. No, sir.

Q. Have you any knowledge as to how much of the sewage of Chicago has been eliminated from the waters of the Illinois by the time it gets to Peoria?

A. No, sir.

Q. Would the pollution (employ that term) of the waters at the bear trap dam be as great as the waters of the Illinois?

A. I don't know, sir.

Q. The pollution at Peoria would be less, would it not, than the pollution at the bear trap dam?

A. I don't know, sir.

2832 Q. Is your opinion based upon any personal knowledge, in regard to the conditions that obtain at Peoria itself?

A. No, sir.

Q. Do you know what the conditions of the waters of the Illinois River at Grafton since the opening of the drainage canal were, whether it is infected with infectious matter or polluted with organic matter?

A. I regard it as quite certain that it certainly, beyond a reasonable doubt, did.

Q. How do you prove that proposition?

A. I didn't prove it. I would like to prove it if I could. The proof would necessarily be somewhat indirect and circumstantial.

Q. Is it susceptible of demonstration?

A. I think it may be.

Q. Has it ever been?

A. Perhaps not absolutely demonstrated. The increased death rate in St. Louis since the opening of the canal is a very strong indication of it.

Q. Well, do you know whether or not the waters of the Illinois River at Grafton has been proven to be infectious and polluted?

A. I believe it has.

2834 Q. In order to prove it infectious what is necessary to be established?

A. The best available proof is the increased death rate among those who use it.

Q. Do you know of any one who uses the water of the Illinois River at Grafton or immediately above Grafton?

A. No.

Q. If you saw these people drinking and knew that these people drank that water, and you knew that those people did not have typhoid fever as a consequence of drinking that water, would you not draw the conclusion from the fact that that water was not infected?

A. If there were a sufficient number of people, if the evidence was clear and conclusive on the point that they drank the wa-

2835 ter, and that they drank it straight, and that they did not have typhoid fever, it would be a very important piece of evidence.

Q. How long does it take the sewage of Chicago to go to the intake at St. Louis at an average flow of water?

A. Somewhere in the neighborhood of two weeks.

Q. How did you ascertain that fact?

A. I have been told that by people who have studied the matter.

2837 Q. You have no personal knowledge on the subject?

A. No, sir.

Q. Assuming, Mr. Hazen, that in the City of St. Louis, the true situation was in 1900 that out of the total number of typhoid fever cases there were 1,213—168 people died. In 1901 there were 1,101 cases and 198 people died—for those two years would you say that the typhoid fever in the City of St. Louis was on the increase or decrease?

A. I should say it was on the increase.

Q. In other words, the more people that die and the less number of cases would be indicative of an increase in typhoid fever, and if few people died and more cases prevailed it would be on the increase?

A. That, in general, would be my conclusion, but I think a full, accurate statement of that would include data upon both points.

Q. In the construction of filters, is there any additional cost

2843 for the filtering of bacteria?

A. There may be.

Q. Aside from the filtering of mud?

A. There often is additional expense. In the case of St. Louis there would not be materially.

Q. The question of the effect of Chicago sewage on St. Louis
2844 is speculative, is it not?

A. To some extent.

Q. What proportion of Missouri River water and Mississippi River water enters the intake?

2846 A. About 30 per cent. Mississippi River water and 70 per cent. Missouri River water.

2857 DR. W. W. WILEY,

Physician, Cumberland, Md.

Q. Do you know of your own knowledge anything about how many cases (of typhoid fever) there were there (in Cumber-
2860 land?

A. There were at least 485 cases reported by the Physicians' Society. I had personal knowledge of 270.

The use of disinfectants by physicians was generally employed
2861 in Cumberland. Of course, in private practice you cannot carry it out rigidly. You cannot enforce it.

Q. In what part of the city was the epidemic most prevalent,
2863 in that along the banks of the river or away from it?

No, sir, away from it.

About 70 per cent. of the patients with typhoid fever were
2865 connected directly with sewage.

I COMMUNICATED WITH A DOCTOR AT HANCOCK, THAT IS A PLACE ABOUT 60 MILES BELOW CUMBERLAND, AND SOON AFTER WE HAD OUR EPIDEMIC IN CUMBERLAND THEY BEGAN TO HAVE CASES AT HANCOCK, BUT I NEVER HEARD THE NUMBER, BUT THEY HAD QUITE A NUMBER OF CASES AT HANCOCK,
2866 AND ACCUSED US OF COMMUNICATING IT TO THEM.

RE-DIRECT EXAMINATION,

By General Crow.

Q. Doctor, was the intake at that time below the place where some of those creeks into which sewers ran emptied into the Potomac?

A. Yes, sir; only about 175 feet, I guess, below. * * *

RE-CROSS EXAMINATION.

Mr. Todd.

Q. How much of the city was built above the waterworks?

A. Let's see. At that time about one-third.

Q. And was the waterworks located below the creeks or small streams that divided the city?

A. No, it was below the stream that, as I say, comes down Fayette and Green streets, and then the creek communicates with it. You see there is a dam along there, forming a basin.

Q. The sewage of Cumberland, a part of Cumberland itself, entered the water above the intake?

A. Yes, sir.

Q. And the water itself that got into the intake was contaminated by the sewage discharged from Cumberland itself?

A. Yes, sir, and these streams above it unite and form one stream, and did come in about 175 feet above the water-
2867 works. * * *

About one-third of the population drained into the river above the intake.

Q. At the time that this epidemic began in December, was it at a high or low stage?

A. Well, about middle, then, sir.

Q. Had the winter set in then?

2868 A. Well, the river don't generally rise. It freezes over, you see, in December, and breaks up then about the latter part of March.

2869 WILLIAM B. STOCKMAN,

District Forecaster U. S. Weather Bureau,, Washington, D. C.

Precipitations given in the Mississippi Valley.

2869 WILLIAM C. WOODWARD,

Health Officer of the District of Columbia, Washington, D. C.

Table of deaths in Washington, D. C., from 1895 by the month to 1902.

Q. Now I will ask you what, in your opinion, is the principal cause of typhoid fever in this city?

A. My own opinion, after a very careful consideration of the
2887 entire subject, is that the chief cause of our typhoid fever is our Potomac River water.

CROSS-EXAMINATION,

By Mr. Todd.

Q. Do you regard the water of the Potomac as the sole cause of the typhoid fever in the City of Washington?

A. No, sir.

We have, of course, a direct infection of one patient from another. A great number of persons who are infected through milk, a certain number who are infected through oysters and vegetables eaten raw, and persons visiting here from other cities, and persons returning from summer resorts who are residents here.

Q. What is the difference between typhoid fever and typho-malaria?

A. I REGARD A CASE OF TYPHO-MALARIA FEVER AS A CASE OF TYPHOID FEVER IN WHICH THE PHYSICIAN HAS MADE A MISTAKE IN THE BEGINNING AND CALLED IT MALARIA FEVER, AND HE SEEKS THE BEST WAY TO GET OUT OF THE HOLE. WE CLASSIFY THEM SEPARATELY, BECAUSE SOME PEOPLE REGARD THEM AS DIFFERENT DISEASES, AND WE FURNISH OUR STATISTICS TO PEOPLE AND LET THEM USE THEM AS THEY SEE FIT. I HAVE EXPRESSED MY OPINION.

Q. But is there a distinction as a matter of fact between typhoid fever, typho-malaria and malarial fever?

A. There is a very marked distinction between malaria fever and the other diseases unless you regard the typho-malaria
2887 fever as typhoid fever. When it comes to typho-malaria and typhoid fever the best authorities today, I believe, regard them as the same diseases.

2889 The number of cases of typhoid fever in Washington in 1902, to the best of my recollection, was about 1,500 or 1,600.

Names of cities and distances from Washington between Cum-
2889 berland and Washington.

Q. Doctor, do you know whether or not any of these towns
2890 have sewers that have outfalls in the Potomac River?

A. I don't know about that.

Defendant rests.

GRAFTON, ILLINOIS.

The Illinois River at this point prior to the opening of the drainage canal was a stagnant water covered with a green scum, contained great numbers of dead fish floating in it; the water had a bad odor and was unfit to drink. Since the opening of the canal the green scum has disappeared from the water, there is no odor, the water is more clear than before. There is a greater volume of water and more current in the river, and there has been no typhoid fever at this point or sickness among the fishermen caused from drinking the water. The water is in a better condition in every way since the opening of the canal than it was before.

These statements are supported by the following witnesses:

V. J. SCHUMACHER, pilot and steamboat man for fourteen years on the Illinois River, with an acquaintance of the river of thirty-two years from St. Louis to La Salle, Illinois. Drank the
2934 water.

JAMES M. ALLEN, president of the Town Council, flour
2948 miller; lived in Grafton fifty-six years.

DR. WESLEY PARK, physician and surgeon for about forty-three years. Lived in Grafton fourteen years. Acquainted
2952 with the river from Grafton to Hardin. No typhoid.

2957 E. MEYSENBURG, banker and merchant. Keeps a boat.

2962 JOSEPH SPANLE, fisherman, since 1851. Drank water.

2964 DANIEL HEATH, fisherman, twenty years. Drinks water.

2967 GEORGE SEIK, fisherman, twelve years. Drinks the water.

2970 ALBERT FREIMANN, fisherman, nineteen years. Drinks the water.

2974 WILLIAM WRIGHT CRANDELL, fisherman, since 1896. Drinks the water.

2976 CHARLES JONES, fisherman, ten years. Drinks the water.

2978 THOMAS COCKSHOTT, fisherman, twenty years. Drinks the water.

2981 MARTIN GILMORE, fisherman, twelve years. Drinks the water.

2984 WALTER RITCHIE, fisherman, twenty-two years. Drank the water.

2987 R. A. SAWYER, fisherman, ten years. Drank the water.

2989 ALBERT LEE, fisherman, fifteen years. Drinks the water.

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HARDIN, ILLINOIS.

Forty-one miles from the mouth of the river. The condition of the water here was similar to the condition at Grafton before and since the opening of the canal, with the exception that in times of low water the greenish scum will be completely across the river. The odor at times is so offensive as to reach several blocks away from the river, and there are about twelve or fifteen fishermen located at this point. The improvement in the river has been marked by the absence of odor, green scum, clearer water, and fish live better in live boxes since the opening of the canal than before. There has been no typhoid fever in the town or among the fishermen using the water for drinking purposes.

This statement is supported by the following witnesses:

CHARLES FLAMM, lived in Calhoun County for the last thirty years, off and on; acquainted with the Illinois River; insurance
2994 agent; ex-county clerk of Calhoun County.

2997 EDW. ATHY, lived in Hardin twenty years; carpenter and joiner.

2999 NATHANIEL BULL, lived in Hardin six years, in the county since 1860; farmer.

3001 M. E. FISHER, merchant; lived in Hardin thirty-five years. Drank the water.

3004 ABNER POOR, fisherman, twenty-eight years. Drank the water.

3009 DR. P. C. BARRY, physician over thirty years. No typhoid fever.

CHARLES H. LE MAR, editor and publisher of newspaper, The Calhoun Herald; acquainted with the Illinois River for forty years.

3015 DR. G. A. WILLIAMS, a physician for twenty-two years, at Hardin. No typhoid.

3017 CHARLES E. COOK, implement dealer and agent of the Eagle Packet Company; lived nineteen years in Hardin; agent for fourteen years.

3019 M. J. PARKER, ex-steamboat man, now orchard farmer. Drank the water.

3024 G. B. CHILDS, farmer.

3028 DR. S. FLATT, physician five years; acquainted with the river; had one case of typhoid fever on the river.

3029 GEORGE L. ADERTON, county clerk, formerly sheriff and collector; lived in Hardin since 1894.

3033 T. J. SELBY, lawyer, member of Fifty-seventh Congress, lived in Hardin since 1884.

3036 E. E. WILLIAMS, cashier of the Bank of Calhoun County; lived in Hardin since 1899.

3041 WILLIAM McNABB, druggist, six years in Hardin. Malarial drugs have fallen off two-thirds since the opening of the canal.

3043 L. M. DAVIS, general merchant; lived in Hardin since 1880 and acquainted with the river since 1855.

3045 WILLIAM N. MORTLAND, postmaster; lived thirty-seven years in Hardin.

3048 JEFFERSON WELCH, fisherman for twenty-one years. Drinks the water.

3050 WILLIAM MORTLAND, farmer and fruit grower; ex-county judge and member of the State Legislature. Wood-boated on the Illinois River. Lived in Hardin since 1848.

KAMPSVILLE, ILLINOIS.

The water at this point before the opening of the drainage canal at low water stages was very stagnant, had a green scum on it, an offensive odor, and fish in low water stages would not live in live boxes, but since the opening of the canal the water is clearer, purer, free from offensive odors, better stages, and swifter currents, fish live better in live boxes than before, no typhoid fever observed since the opening of the canal, and no sickness among the fishermen and malaria fever has been on the decrease. There are about forty fishermen at this point. Scum would form on the nets of the fishermen.

This statement is supported by the testimony of the following witnesses:

3052 C. B. BRAKESVILLE, fisherman along the Illinois River all his life. Drinks the water.

3057 EDW. HEATON, fisherman forty-two years. Fished at Chillicothe, Peoria, Beardstown, Meredosia, Montezuma, Bedford and Kampsville. Drinks the water.

3062 JAMES MORAN, fisherman for fifteen years. Drinks the water.

3067 IRA DAVIDSON, fisherman. Drinks the water.

3071 W. L. FLATT, fisherman ten years. Acquainted with the Illinois River forty years. Drinks the water.

3073 ISAAC STABLER, fisherman twenty-eight years. Drinks the water.

JOHN M. HIPPLE,

Pilot on the river, in the employ of Government.

Have been in the employ of the Government three years last May. Have lived on the river all my life. Have ferried and
3080 fished and steamboated.

Q. Does the character of the bottom of the Illinois River vary at different places upon the river?

A. Why, yes, at some places it is mud and at some places it is sand, and at some places it is hard mud—what they call gumbo. You cannot shovel it and you cannot cut it and you cannot wash it.

Q. Prior to the opening of the drainage canal was there in the bottom of the Illinois River a large amount of sediment?

A. Why, there was in places, but not in the channel, but out at one side, and behind the islands, and where there was slack water and the river had filled in, there was, but it had not filled in in the channel. Around the creeks and where the creeks empty it fills
3081 in some and changes.
3083 The Illinois River improves from Peoria down.
3086 Drinks the water.

Men in the employ of the United States Government and the fishermen as a general thing drink the water.

Q. As to whether the channel fills up, do you find the channel filling up again?

A. Yes, sir; quite often it does. It don't fill up every time a creek comes out.

3088 * * * * *

Q. To what do you, as a Government employe, attribute the filling up?

A. Well, the creeks throw the mud out; it comes down out of the hills, fills the creek and settles there until they get current enough to carry it away.

Q. In times of flood, does the Illinois River wash out all the sediments deposited between its bank and carry it away?

A. Not always.

Q. In times of flood what is the effect of the deposit in the Illinois River outside of the running channel; are they increased or diminished by he flood?

A. It was increased by this year's flood, but as a general thing
3089 it is diminished.

FRANK TOZEN.

Occupation, steamboat engineer for about fifteen years or more years on the Illinois River. Have traveled the entire length of the river from La Salle to Grafton. Now in the employ of the Government as engineer and blacksmith and have dredged over eight
3101 years as a steady work.

Q. What causes the formation of bars in the Illinois River?

A. I think very nearly the whole cause is the sediment that comes out of the creeks. After each high water there will be a sediment of an inch to two inches, sometimes maybe three inches from the banks. On the flats will be an inch to three or four inches of the sediment after a long high water. This year there was about three inches.

Q. When there is high water in the Illinois River does it wash out the sediment or cause more sediment to settle?

A. I think it causes more sediment to settle? THERE IS NOT CURRENT ENOUGH IN THIS RIVER TO WASH OUT ANY THING.

Q. Have you ever dredged out a place upon the Illinois River where afterwards you were not able to find the channel again?

A. Yes, sir.

Q. Where was that?

A. That was at Otter Creek bar. We dredged it out and then moved up on the other bar, and in two or three weeks we had to go back and dredge it again.

Q. What caused that channel to fill up?

A. Otter Creek. A storm came right after we left there and after the storm we went right back there and couldn't find where we left. That was two or three weeks after we left there, I think it was two weeks.

Q. Did the channel fill up because there was a flood in Otter Creek?

3103 A. Yes, sir.

Q. When you have once dredged out a channel in the Illinois River, through a bar, what causes the bar to again form in the channel?

A. Because there has been a flood in the creek. I have
3104 dredged bars where it was quicksand and came back.

We have forty to forty-five men connected with the fleet who drink the water of the Illinois River without any injurious effects.

3110 VALENTINE TOTZELL, fisherman since 1874.
3115 O. C. BARTHOLOMEW, fisherman, fishes with eighty nets; ten years in Kampsville. Drinks the water.
3116 WILLIAM MAPPIN, fisherman, seven years. Drinks the water.
3119 DR. T. O. HODESTY, practiced since 1896. No typhoid along the river. The typhoid in the hills.

EDWARD DOUGHERTY,

Carpenter; lived in Kampsville twelve years, being on the Illinois River thirty years; employed by the Government on the Illinois River since the spring of 1882 as carpenter and cranesman on the dredges. Been connected with the dredging business for
3122 twenty-one years from Havana to Grafton.

Q. Have you had occasion, during your experience, to dredge out the same channels in the Illinois River more than once? If so, where, and how frequently at each place, commencing at the upper portion of the river and proceeding towards Grafton?

A. As far up as I can remember distinctly, the first was at the mouth of Sugar Creek. I think we dredged that once after the channel dredging and the next place was down there at Otter Creek. I think we dredged that twice after the first dredging. I don't
3123 believe I remember any more places.

We have dredged several places three or four times. * * *

Q. Are you familiar with the Illinois River and have you been upon it in all of its various stages from high to very low water?

A. Yes, sir.

Q. What is the effect upon the bottom sides of the channel of the Illinois River of floods in the river as to the deposit of sediment?

A. I have not noticed any serious results from the sediment.

Q. In times of flood or high water in the Illinois River is the sediment which has been deposited by the action of the water washed out or is more sediment deposited? IN OTHER WORDS, DOES THE RIVER SCOUR?

A. No, sir.

Q. After a flood in the Illinois River, is there more sediment along its banks or less than before a flood?

3124 A. More sediment every time there is a flood.

There are about forty-five men employed by the Government during dredging operations who drink the Illinois River water.
3125 and I know of no case among them of typhoid fever.

DR. FRED. W. RUNDE,

Have practiced since 1898. Had two cases of typhoid fever about three miles south of Kampsville and one and one-quarter miles from the river, and was not to my knowledge attributed to drinking water.

Anti-malarial medicines in my drug store have been a great
3133 deal less since the canal was opened.

ALBERT R. ZIMMERMAN,

Ship carpenter and calker by trade. Have been on the river forty-three years. Am familiar with the Illinois River from Twelve Mile Island to Havana. Never heard of a case of genuine typhoid fever on the banks of the river in my life. Drank the Illinois River
3136 water.

C. V. BRAINARD,

Have been in charge for the last twelve and one-half years of the dredging operations by the Government on the Illinois River from Copperas Creek to the mouth. The dredging is done for the
3139 purpose of deepening the channel.

Q. Do the channel and the new bars that are formed sometimes fill up?

A. The dredge channels fill up at times, yes, sir.

Q. From what cause?

A. Between Kampsville Locks and the mouth of the river it is usually formed by the back-water of the Mississippi. There are times at which the creeks, pouring out a flood of certain stages of the river, will fill up the channel immediately below the mouth of the creek.

Q. What is the effect upon the sedimentation in the Illinois River of a flood?

A. My experience has been that there is no effect on what
3140 has already been deposited.

Q. Before the opening of the drainage canal in January, 1900, did the Illinois River scour and clean itself in times of high water?

A. I never knew of it doing so.

Q. Since the opening of the drainage canal, does the Illinois River scour and clean itself?

A. No more so than it did before.

Q. Before and since the opening of the drainage canal, if sedi-

mentary matter is deposited in the Illinois River, how is it removed?

A. The only way that it is removed is by dredging it or some mechanical process. THE RIVER DOESN'T CLEAN ITSELF AT ALL THAT I HAVE BEEN able TO FIND OUT.

JAMES R. FULLER,

Overseer, Illinois River crew.

Have been in the employ of the Government thirteen years. Have charge of the repairs and construction work and dredging operations under the supervision of the assistant engineer when he is 3144 here, and when he is not there, the same duties that he has.

Q. Where are the bars formed as a general rule, with reference to the mouth of tributaries of the river?

A. Generally below the mouths of these tributaries.

Q. What causes these formations?

A. The flood washes it down from these tributaries, the deposits are washed down by the floods out of these tributaries.

Q. Do the channels cut in these bars ever fill up?

A. Yes, sir.

Q. From what cause?

A. Freshets out of these tributaries.

Q. Have you occasionally redredged the channel formerly dredged out?

A. We have. * * *

Q. What is the effect, so far as sedimentation is concerned, of a flood in the Illinois River?

A. It would make some deposit along the banks at the lower end; if we have back-water from the Mississippi it is liable to make deposits in the main channel.

Q. Does it have the effect to lift up and remove sedimentary matter previously deposited either in the channel or along the banks of the river?

A. I have never seen any effect of it.

Q. In the Illinois River, if sedimentary deposits are made or occur, what is the means of removing them?

A. Dredging, as a rule, in some form or other.

Q. Did the Illinois River, before the opening of the drainage canal, scour or clean itself in times of flood?

A. Not as I ever saw.

Q. Since the opening of the drainage canal, does the Illinois River scour or clean itself, in either times of flood or in other stages of water?

A. No, sir.

Q. Since the opening of the drainage canal, if sedimentary matter occurs in the Illinois River, what is the only means of removing it?

3145-3146 A. Dredging.

CROSS-EXAMINATION.

Q. You don't mean to say that in times of high water the river does not cut through these bars and deposits and at places form new channels, do you?

A. Yes, sir; that is what I mean to say. It doesn't do that. The river don't cut out channels, don't change a channel from itself. It won't cut a channel from these bars.

Q. Then the channel, you say, never changes either in high or low water?

A. Not in my experience. It never changes from the river itself. The current never changes. We changed the channel occasionally dredging. I never saw this river change a channel from the effects of the water.

Q. You are not an engineer?

3147 A. Yes, sir; I have studied civil engineering.

JOHN WEIMER,

Live at Gravel Point for three months. Previously was employed by the Government as dredge engineer in the neighborhood of about sixteen years on the Mississippi and the Illinois Rivers. Am acquainted from La Salle to the mouth of the Illinois River and have dredged from Hennepin to the mouth. Am acquainted on the Mississippi River from Winona to about twenty miles below St. Louis.

Q. How does the Mississippi River and the Illinois River compare as to their channels?

A. They don't compare at all, the two rivers. Why, one would stay stationary in its place and the other moves.

Q. Which one moves?

A. The Mississippi.

Q. And the Illinois stays stationary?

A. Yes, sir.

Q. Is it the Mississippi River that scours?

A. Yes, sir.

Q. How about the Illinois? Does it scour?

3149 A. No, sir.

Q. Will high water in the Illinois River scour out the bed of the river?

3150 A. No.

Q. How are these bars removed when they are removed in the river?

A. By dredging. We removed them by dredging.

I have had experience where we dredged out the channel and

3151 it immediately filled up and we had to dredge it out again.

Q. When matter is deposited on the bed of the Illinois River, do you know of any way by which that deposit can be removed except by dredging?

A. No, sir.

Q. Does high water or current change the channel in the Illinois River?

A. No, sir.

Q. What effect does current and volume of water have upon the channel of the Mississippi River, if you know?

A. Well, I have seen where the channel would be one time and after high water it would be altogether removed from there, and up at another place.

Q. That condition is common on the Mississippi, is it not?

A. Yes, sir.

Q. Have you ever found that condition to exist upon the Illinois?

3152 A. No, sir.

GRAVEL POINT, ILLINOIS.

The water of the Illinois River at this point was in a very bad state prior to the opening of the canal, and has greatly improved by virtue of the canal being opened.

This is supported by the following witnesses:

3157 THOMAS J. NELSON, fisherman, about six years; also a farmer.

3160 THOMAS CARTER, fisherman for forty-five years. Drinks the water.

3163 GEORGE NELSON, fisherman for about six years. Drinks the water.

3165 S. D. THURSTON, fisherman for three years; previously farmed. Drinks the water.

PEARL, ILLINOIS.

The condition of the water at Pearl is practically the same as the condition of the water at Gravel Point prior and subsequent to the opening of the drainage canal. About this point it became evident that prior to the opening of the drainage canal in winter, when a hole was cut through the ice, a gas would emanate from the water and dead fish would be found on the ice, and also a filthy scum on the water.

3167 MARION HESS, fisherman and farmer for twelve years. Drank the water.

3178 WESLEY FRISE, fisherman for twelve years. Has fished as far up as Hennepin.

3183 JOHN WILDT, have been in the fish business. Am a buyer and shipper of fish and have been in the business for eighteen or nineteen years. Also drank the water.

3186 JOSEPH HALL, fisherman for three years at Pearl, and since 1881 at other places along the Illinois River.

GEORGE HOPLER, fisherman for twenty-four years.

NAPLES.

About thirty-eight miles from Kampsville and about twenty-six miles from Pearl and twenty-five miles from Beardstown, and thirteen miles from La Grange Dam.

The water of the Illinois River, prior to the opening of the drainage canal, was much more foul than the water at Kampsville or Grafton. In low water, it was very stagnant and foul and fish would not live in it. During the summer a scum would form on the water and quite an odor. A kind of substance would form on the net of the fishermen like grease, and called by the fishermen slurgut. Fish would die in the nets under the ice in winter. Since the opening of the canal the water has greatly improved over conditions that obtained previously in every respect. No typhoid fever exists among the fishermen who drink the water of the Illinois River.

W. H. WATERS, a fish dealer. Have been engaged as a

3192 fisherman; am acquainted with the river for about fourteen miles. Have put up ice off the river for about eight years.

3196 WALLACE HART, notary public and town clerk. Lived thirty years in Naples. Sixty-nine years old. Acquainted with the Illinois River all his life. Ten or twelve fishermen here.

3199 WALTER SURRATT, lived in Naples twenty years; fisherman.

JAMES WATERS, fisherman ten years. Fished about forty-six miles of the river. Drink the water as well as the other fishermen.

BENJAMIN FRANKLIN ECKLES, farmer. Have lived for four years within eight feet of the bank of the river and have lived in the vicinity of the river for forty-six years. Use the water
3208 for drinking and domestic purposes.

MEREDOSIA.

The water at this point was about the same as the condition that existed at Naples, as evidenced by the testimony of the following witnesses:

3211 JOHN CHRISMAN, workman, net fisherman for about twenty years.

3214 JOHN L. GRAHAM, fisherman, about eighteen years.

3217 GEORGE S. LEWIS, hotel man. Lived here six years.

WILLIAM HAUSER, ferryman for sixteen years, running a cable ferry.

3222 REV. R. G. LINKER, minister of the gospel in the Evangelical Lutheran Church.

3224 A. J. LESHE, dealer in grain; lived here nearly thirty years. On the river every day.

3226 F. A. NEVILLE, physician and surgeon; practiced sixteen years here. In Meredosia have not had to exceed one-half dozen cases of typhoid in the last three years, and they were not attributed to the water of the Illinois.

3228 S. D. ALLEN, employe of the Wabash Railroad pumping station. Have lived here twenty-five years. Drank water.

J. P. BAUR, fish culturist in the employ of the United States Fish Commission for about fourteen years.

LA GRANGE LOCKS.

The water at this point prior to the opening of the canal was practically in the same condition as heretofore stated at the other places, but since the opening of the canal it shows less clearing up and purifying that was observed at other points down the river.

3238 JOHN D. KERR, superintendent of La Grange locks.

3247 BENJAMIN COLE, general workman at the locks.

BEARDSTOWN.

The condition of the water at Beardstown prior to the opening of the canal in low water was highly polluted, having a thick scum on the surface during low stages of water; in winter fish died under the

ice; fishermen complained of the presence of slimy substance which collected on their nets, known as slurgut, which substance appeared in great abundance. The odor from the water was very offensive and disagreeable. According to the health officer, no typhoid cases existed before or since the opening of the canal; since the opening of the canal the water has been clearer; the presence of this slime has not been so pronounced, the odor and scum from the water has disappeared, and the general sanitary condition of the water has been greatly improved. The foregoing statement is supported by the testimony of the following witnesses:

3255 DR. GEORGE BLEY, practicing physician for twenty-two years at this point. Have had ten to twenty cases of typhoid fever during the last three years from people who drank water from the river and otherwise.

3260 L. W. GOODELL, wholesale and retail ice business and fish business. Have resided in Beardstown since 1877.

3264 H. EHRHARDT; have lived in Beardstown fifty-one years. Am a physician, practicing twenty-six years, and health officer. Have observed no cases of typhoid fever before or since the opening of the drainage canal. Have not known of any people dying of typhoid fever in the last four or five years in Beardstown.

3268 ED. F. HARRIS, in the fish business and a fisherman for the last eighteen or twenty years from Peoria to Kampsville. Drank the water.

3271 MARTIN McDONOUGH, hotel man. Fished with rod several times a week every year.

3273 THOMAS K. CONDIT, cashier of the First National Bank. Have lived in Beardstown since 1874.

HAVANA, ILLINOIS.

The water at this point was considerably more polluted prior to the opening of the drainage canal than at points further down the river. The effects on fish were more manifest. The slime collected on the nets was in greater abundance. At this point was first noted the presence of the large island of offal from the cattle sheds at Peoria, and one in particular was unable to pass through the piers of the bridge located at this point. The scum and odor from the water was very offensive; since the opening of the canal the water has become clearer and purer, the fish have lived better, and the slime, while more evident at this point than at Beardstown below, has been considerably mitigated and the general sanitary conditions of the water have been greatly improved and no typhoid fever exists in this town. The foregoing statements are supported by the following witnesses:

3286 O. H. HARPHAM, postmaster. Have lived in Havana fifty-eight years. Have been acquainted with the river all my life. The owner of a launch.

3291 GEORGE W. BUNKER, an upholsterer; lived in Havana twenty years. Formerly employed on a steamboat running to East St. Louis.

3295 DR. C. M. MORRILL, physician and surgeon. Lived in Havana for ten years. Have seen no typhoid fever since the opening of the canal.

3298 L. A. EVERIST, fisherman. Lived in Havana thirty years. Have fished about fifteen years. Have seen fish condemned for market purposes at this point.

3310 JOHN McGARVY, fisherman for twenty-six years, from La Salle to Beardstown. Drinks the water.

3317 RICHARD L. ENGLAND, fisherman for thirty years. Have fished twenty miles above and twenty miles below Havana.

3320 GEORGE E. McHOSE, business, a boat livery and mayor of the city.

3322 PHILIP DREFFENBACHER, physician and surgeon. Practicing in Havana about forty-eight years. No typhoid.

PEKIN.

The condition of the water at this point before the opening of the canal was exceedingly foul, bad smell, fish did not thrive and the conditions were worse than below, and since the opening of the canal the conditions have greatly improved, but not as much as at Havana, Beardstown, and positions below. The distilleries are located at this point and the testimony of the distillers is set out more in detail. The facts above set forth are proven by the following witnesses:

3327 C. G. HERGET, manager of the Globe Distillery, located about half a mile from the Illinois River. The slop is fed three times a day to the cattle and divided equally about three pecks to the steer a day; that is, three pecks of slop. We feed 4,400 head of cattle under one roof. The excreta from the cattle is car-

3329 ried into the river through troughs connected with the cattle shed. The cattle are fed twice a day about one-quarter pound of salt to the steer.

3338 DR. C. G. MUEHLMANN, health commissioner of Pekin. The deaths from typhoid from 1900 to 1901, 1; 1902, 2; 1903, up to July 1st, 1.

3344 H. G. HERGET, manufacturer of beet sugar and director of the Corn Products Company, which is a glucose factory.

E. W. WILSON,

President of the American Distillery Company and also of the German-American National Bank. Feed about 4,000 cattle.

The excreta of the cattle shed goes out on the banks of the
3353 river and into the Illinois River.

Q. How many cattle have been fed at the American Distillery in the manner you described in 1900, 1901, 1902, and thus far in 1903?

A. About 6,000 head each year.

Q. How many cattle are you feeding at one time?

3355 A. About 4,000.

Q. State in a general way how many tons of solid matter are deposited by your distilleries on the banks of the Illinois River in a month, day or year?

A. Well, there is about 200,000 pounds of excrement per day.

WILLIAM Z. CONZLEMAN,

Mayor of the Town of Pekin and one of the managers of the
3363 Globe Distillery.

Q. How many cattle are fed yearly in the distillery of which you are manager?

A. About 4,500.

3367 HARRY TAYLOR, fisherman since 1895, from twelve miles above Hennepin to La Grange dam. The water before the
3368 opening of the drainage canal was rotten.

3370 J. C. LOSCH, steamboating and ran a boat of my own for twelve or fifteen years. Have been on the river fifteen years.

3371 Have seen fish dead at the locks in such quantities that my steamboat wouldn't carry them.

3372 Saw the Peoria islands in the Illinois River. Have used my boat for breaking them loose from the shore.

CHILLICOTHE, ILLINOIS.

The water before the opening of the drainage canal was in a highly polluted condition, but not so much pollated as condition below Peoria. In the winter season, when holes were cut in the ice, the water would smell and fish would die in the nets shortly after they were caught, and in the winter the fish had a taste of gas and tar that rendered them unfit for market. The green scum which was observed below Peoria which attached itself to the nets did not appear in the water at Chillicothe, which is above Peoria. A kind of a gas

emanated from under the ice after a hole was cut through which resembled the smell of gas or tar. Since the opening of the canal the water has greatly improved, fish live better in live boxes, the water is not as contaminated, much clearer, fish thrive better, the scum and odor is absent from the water and there is no typhoid fever existing among the fishermen. These facts are substantiated by the following witnesses:

3374 JERRY FOLSOM, a fisherman for forty years from Chillicothe to Spring Valley.

3378 BRADLEY B. HAWLEY, a captain of a steamboat, steamboating about forty-three years on the Illinois River; acquainted with conditions above and below Peoria. Water is better for steam-making purposes than before the opening of the canal.

3390 O. F. THOMAS, physician and surgeon. No typhoid in the city, with the exception of two cases which were not attributable to the river.

3394 WILLIAM COLWELL, lived in Chillicothe since 1847. Contracting business, connected with bridge building. Acquainted with the river below Peoria and above Peoria.

Q. You judge from its appearance and not from what it may contain?

A. Well, I judge from using it in my engine boiler, the difference in the smell of it, etc.

3399 3400 J. D. DALRYMPLE, a fisherman on the Illinois River for about sixteen years. Fished from Hennepin to Copperas Creek.

3404 SAMUEL HAUSSLETON, occupation, farmer and fisherman with a pole and line. Lived on the river since 1864.

3410 JOHN DAVIDSON, occupation, fisherman for forty years. Have fished from Spring Bay to Lacon. If you would take a fish out of the spring water and put him back fifty yards frrom the edge of that water into the ice he wouldn't live as long as he would out on the land.

3412 A. C. WILKE, occupation, running a boat rod and a fisherman for about ten years from Hennepin to Beardstown.

3416 MARTIN TRUITT, occupation, fisherman for the last twenty-five years. Fished from Lacon to Peoria.

3419 CHARLES F. SCHMIDT, fisherman for twelve years from Copperas Creek lock as far as Hennepin. You couldn't keep fish alive very long, that is, in live boxes, but it wasn't as bad here as it was below Peoria.

3421 E. N. NELSON, fisherman for twenty years between Lacon and Peoria.

3425 JESSE HORN, fisherman for thirteen years between Hennepin and Peoria.

3428 T. H. HARRIS, fisherman for about ten years between Peoria and Lacon.

3431 L. S. McCULLEY, stationary engineer for six years and also upon the steamboats running from Copperas Creek to Henry.

LACON, ILLINOIS.

The condition of the river before the opening of the drainage canal was not so good as the condition at Chillicothe. The fish would not live under the ice in winter and tasted of tar. There was a good odor from under the ice in winter and a disagreeable odor in summer. Since the opening of the canal, the condition of the water has been greatly improved in every way. No typhoid fever at Lacon. The above statement is supported by the following witnesses:

3435 WILLIAM MANGLE, fisherman for eighteen years between Henry and Chillicothe.

3440 JOHN BARMEISTER, fisherman since 1867 from Henry as far as Pearl.

3443 WILL REED, fisherman and fireman on steamboats and have traveled from Peoria to La Salle and from Peoria to St. Louis. Notice the difference in the steam-making qualities of the water before and since.

3448 FRED MAWLEY, fisherman for twenty-five years. Have fished from La Salle to Naples. Only one man died of typhoid

3449 fever in town yesterday. The only case I have heard of.

3451 HENRY STOEHRS, engineer at the woolen mills.

3454 JOHN FAY, fisherman, Illinois River, fifteen years. Have fished the river from La Grange to Lacon.

3456 WILLIAM B. McKINLEY, engineer on the boat "Illinois."

J. W. POTTS, a physician in Lacon for eleven years.

Q. Do you know of any typhoid fever in this community within the last three years, Doctor?

3460 A. No, sir.

3462 S. S. EVERETT, physician and surgeon. Lived in Lacon seven and one-half years and have practiced in this vicinity for ten and one-half years. Have had three cases of typhoid, which were imported.

HENRY, ILLINOIS.

The same condition obtains at Henry as obtained at Lacon prior to and subsequent to the opening of the drainage canal, as evidenced by the following witnesses:

3466 CLYDE BANTER, fisherman for the last nine years. Have fished three miles below Copperas Creek and clear to Spring Valley.

3472 B. F. FORREST, physician and surgeon; practiced in Henry for thirteen years; occupied the position as mayor of the city. Have two cases of typhoid fever, and are from patients who have visited in Indiana. There have been no deaths from typhoid fever since the opening of the canal.

3478 ELMER MEELICK, lock tender at Henry Lock since 1900; prior to that was on the steamer "Peoria;" am acquainted with the river from Henry to Peoria.

3489 A. G. HUMPHREY, in the grain business for over twenty-one years. Have fished and hunted upon the Illinois River.

3490 W. T. LAW, a banker. Have lived in Henry for forty-four years. Acquainted with the river.

FRED BOUTER, fisherman for ten years, and ran a steam tug in connection with fishing on the river.

3495 H. HALL, iceman, in the ice business for nine seasons.

LA SALLE, ILLINOIS.

Population, about 14,000.

Prior to the opening of the canal the water at this point was dirty looking at times. A green scum would form upon the water during the low stages, and it had a very strong odor. There was practically no fish found in the river at this point. Since the opening of the canal the water has greatly improved over conditions which previously obtained; it has a better color, the fish will live longer in the water, and conditions, from appearances, have in every way greatly improved. There has been no increase of typhoid since the opening of the canal, notwithstanding the fact that one-third of the water supply comes directly from the Illinois and Michigan canal. These facts are substantiated by the following witnesses:

3719 ROMAN J. RIMMELE, tinner, acquainted with the Illinois River for forty-five years. On the river on an average of two to three times a week. Running a launch with excursion parties.

3722 WALTER A. PANNECK, attorney and mayor of the City of La Salle. About two-thirds of the houses connected with sewers.

3734 CHARLES H. NICHOLT, civil engineer of the City of La Salle.

3744 JOHN GRUB, fisherman. Have drank the water since the opening of the canal.

3745 CHARLES RIMMELE, boat business between ten and twelve years. Running a pleasure craft.

3751 W. E. STAFFORD, manager Postal Telegraph Company; lived in La Salle seven years. Been running a boat with Mr. Masterman from La Salle to Starved Rock.

3753 F. L. MASTERMAN, agent for Adams Express Company. Have lived in La Salle for thirty years. Have hunted a great deal up and down the river from Ottawa to Peoria. Have been on the river a great deal running steamboats.

3755 C. L. DIESTERWEG, shoe merchant; lived in La Salle about forty years and am acquainted with the river, having fished and hunted and swam in it since the opening of the canal.

3757 DR. FLOYD CLENDENNEN, physician and surgeon. Practiced in La Salle for about thirty years. There is very little typhoid in the city at present. Have had less typhoid to treat last year than ever before.

OTTAWA, ILLINOIS.

Prior to the opening of the canal the water here was almost sewage water, with a very disagreeable odor, and since the opening of the canal the conditions have greatly improved, as supported by the testimony of the following witnesses:

3774 HENRY MAYO, attorney at law and postmaster, Ottawa. Member of the Illinois River Valley Association.

3782 CHARLES E. HOOK, cashier of the First National Bank and mayor of Ottawa.

3784 M. T. MALONEY, lawyer, ex-mayor of Ottawa, ex-attorney general of the State of Illinois.*

3790 J. O. LESLIE, school teacher; lived in Ottawa fifteen years.

3794 JAMES F. FARRELL, newspaper man and city clerk.

3805 DANIEL C. WOODS, clerk in the Clifton Hotel, Ottawa, and gauge reader for the United States Geological Survey. Acquainted with the Illinois River for forty years.

3811 GUSTAV KNEUSSL, druggist.

MARSEILLES, ILLINOIS.

The condition of the river before the opening of the canal was very bad; since the opening of the canal there has been a marked improvement, as evidenced by the following witnesses:

* The testimony of Mr. Maloney will bear reading to the court.

3815 T. W. THIRY, cigar manufacturer. Lived in Marseilles about eight years.

3817 G. W. SMITH, furniture business, and ex-mayor of Marseilles. Lived in Marseilles thirty years.

3821 DONALD A. NICHOLSON, police magistrate. Lived in Marseilles forty years.

3827 JAMES BRUCE, lived in Marseilles eight years, a grain merchant.

3830 W. H. SPENCER, grocer, lived in Marseilles all his life.

3833 A. S. GUMM, teaming. Lived in Marseilles sixty years.

3835 H. R. ADAMS, manufacturer of agricultural machinery. President of the Marseilles Manufacturing Company. Lived in Marseilles thirty-six years.

3838 H. B. McKAHIN, assistant secretary of the Marseilles Manufacturing Company. Lived here since 1871.

3840 N. T. SMITH, ran a livery stable about twenty years and have retired from business. Is a farmer.

3842 G. H. SWADER, foreman of the Marseilles Manufacturing Company.

3844 LEANDER G. DOUGLAS, farmer and land owner and cattle raiser.

3847 GILBERT HOWLAND, lived in Marseilles fifteen years and in the vicinity of the Illinois River for sixty years.

3849 H. W. COLLIER, running a pool room and street sprinkling business, and have lived in Marseilles since 1870.

3851 J. W. VAN LOON, a painter; lived in Marseilles eleven years; fished upon the Illinois River.

MORRIS, ILLINOIS.

The water at this point was bad before the opening of the drainage canal, and has been greatly improved since the opening. Prior to the opening of the drainage canal the odor from the river was very offensive, and this odor has practically all disappeared, as evidenced by the testimony of the following witnesses:

3855 HENRY COOPER, harness business; lived in Morris for thirty-seven years.

3860 H. M. FERGUSON, a physician and executive officer of the city board of health and served three years as such.

3873 DE WITT C. HOUSTON, a member of the board of review; lived in Morris since 1874.

3876 L. B. RAY, ex-member of both houses of the State Legislature

and ex-lieutenant governor of the State of Illinois, and lived in Morris since 1875.

3880 CHARLES D. FERGUSON, blacksmith; lived in Morris since 1854.

3882 G. M. ELDERLING, photographer; lived in Morris for twenty-six years.

3887 HENRY STOCKER, boot and shoe business.

3890 J. O. LERETTE, saloon business in Morris about twenty-eight years.

3892 J. C. HORRIE, jewelry business about twenty years in Morris.

3894 FRED SLACK, deputy sheriff of Grundy County.

PEORIA, ILLINOIS.

H. E. BEASLEY,

5498 City Engineer of Peoria.

3500 Population of Peoria is about 70,000 to 73,000.

We have official records in the office of the connection of about 2,500 connections with the public sewers. This record is not completed, and I would judge that there would be in the neighborhood of 3,000.

3501 The drainage of the manufacturers and the surface drainage empties into the public sewers and from thence into the Illi-
3503 nois River.

The corporate limits of the city are 8.40 square miles. Of this 3.41 are sewered, being about 40 per cent. of the total.

I would state in my opinion about one-quarter or one-third, or about 33 per cent., discharge their sewage into the city sewers.

3504 PETER CASEY,

Manager of the Corning Distillery Company since June, 1901, from August, 1895, to June, 1901. Was manager of the Whisky Trust, known as the American Spirits Company, commonly called the Whisky Trust. At the time I had the management there were four active distilleries located in Peoria.

Q. From 1895 to 1900 about how many cattle were fed by the distillery over which you exercised supervision?

A. Well, it ranged from 20,000 to 12,000. The most we ever fed was in '96, I think. We fed 20,000 then.

Q. How many were fed each year after that from 1896?

A. Well, I think in 1897, to the best of my recollection, somewhere in the neighborhood of 15,000. In 1898, I think, it was probably 12,000 or 14,000. In 1899, I think, probably we fed 12,000. In 1900, I think, we probably fed 8,000, possibly 10,000. I don't know just exactly. I have not got the data. In 1901, I think, it was 10,000.

In 1902, I think, we fed at that time 8,000.

3509 Q. Describe the cattle sheds in which the cattle are fed and the manner of feeding them.

A. Well, the sheds are built where there are trough racks. The cattle stand with their tails together in the one section. They are built in sections. The slop is supplied to them—a large tub is pumped into it from the distillery. The offals from the cattle are pushed out not less than twice a day into a sewer which is directly behind each steer, one head this way and one head this way, and they are behind each steer, that is pushed out into the main sewer, that runs through the middle of the cattle barn, and water is used to flush that into the river.

Q. What else is fed to the cattle besides slop?

A. Hay and cottonseed hulls and sometimes cottonseed meal.

Q. What is the purpose of feeding hay, cottonseed hulls and cottonseed meal?

A. The object of feeding hay and cottonseed hulls is to retain the slop. Otherwise it would run through and they wouldn't get any benefit of it. Cottonseed meal is used to advance the cattle when they have not sufficient slop to feed them with.

Q. How many cattle are fed from the slop of one bushel of corn?

A. The rule is to feed a bushel of slop to every steer, but lately that has been modified considerably. They don't feed them that now. About three-quarters of a bushel, and finish up with cottonseed meal or something of that kind to tide them over.

Q. How many gallons in the bushel of slop?

A. There is about thirty-one gallons. That goes to the cattle. * * *

Q. About how much hay is fed to a steer daily?

A. * * * I should judge somewhere in the neighborhood of seven to ten pounds, sometimes as high as fifteen. * * *

Q. About how many pounds of hulls are fed on an average?

A. Well, from one and one-half to two pounds.

Q. Are the cattle salted?

3510-3511 A. Yes, sir, salted frequently.

Q. How much salt is consumed a week in the feeding of 10,000 head of cottle?

A. Well, I should judge about ten or fifteen barrels.

3512 Q. How far are the cattle sheds at Peoria located from the banks of the river?

A. Some of them are directly on the bank of the river, and the furthest, I think, is about 700 feet.

Q. When this offal or excreta of the cattle is carried to the river what becomes of it?

A. Well, the current takes it down, I suppose, and in running where you have quite a distance to run that out there is a large trough that runs from the cattle barns to the river. Sometimes the hay is thrown off to the ground on both sides, and it doesn't run through the trough into the river.

Q. How extensive are these accumulations?

A. Well, they have been pretty extensive. This last high water took them all away again. About two years most of them

3512 were removed.

Q. Have they at any time been dislodged by steamboats and floated down the river in large islands?

A. Oh, yes. * * * The islands several times lodged against Pekin bridge down there. I was notified by the Board of Health to come down and take it away and we did so. After that we never heard anything from it.

3513 Q. Will you describe the condition of the river at Peoria before the opening of the drainage canal?

A. Well, the condition of the river at Peoria before the opening of the drainage canal below Peoria was very bad. It smelled so bad sometimes we could hardly stand it along there. The water seemed to be perfectly stagnant, and there was no life to it at all. * * * I have noticed a foam in it. * * * I think it was the offal from the cattle barns, in my opinion.

3513 Q. Since the opening of the canal, and the turning of Lake Michigan water into the Illinois River, what has been its effect upon the condition at Peoria, both where the water of the Illinois River receives the sewage discharge from the distillery and cattle barns, as well as above the point where such sewage is received into the Illinois River?

A. Well, I consider that it is very much improved in every way, especially for mechanical purposes.

Q. How about the stench in the river from the place of contact

with the sewage of the distilleries, meaning by that the outfalls from the cattle sheds for four or five miles down stream?

A. I have not noticed any stench since the opening of the canal to amount to anything.

Q. Have you noticed any improvement in the Illinois River from the railroad bridge down stream for a distance of three or four miles since the opening of the drainage canal, and the conditions previous to that time?

A. Yes, there is a great improvement in the river.

Q. What is the condition of the waters to-day as compared with before the opening of the drainage canal as to purity?

A. In my opinion it is purer than it was before.

Q. Please state what facts and reasons you have for entertaining that opinion?

A. Well, I only know these facts in a mechanical way. That is, the water in our boilers, we don't have that foaming now as we used to have, and we don't have that slimy formation on the boilers
3514 or condensers that we formerly had.

LOUIS A. McFADDEN,

Physician and surgeon. Have practiced medicine in Peoria County for five years. Was United States Pension Examiner, Alderman from the First Ward and Commissioner of Health from October, 1901, until June, 1903.

Q. In your judgment, how many people in or near the City of Peoria live either immediately upon the banks of the river or upon the water of the Illinois River?

A. Well, I think when I was county physician there must have been as many as 500 living in cabins on the river and along the river.

Q. What was the condition of the health of the people living along the banks of the Illinois River in this vicinity prior to the opening of the drainage canal in January, 1900?

A. I found a great deal of sickness among them, more than in any other part of the city.

Q. Of what character of diseases?

A. Malaria, malarial diseases, dysentery and typhoid fever.

Q. To what do you attribute these diseases at that time?

A. Principally to their mode of living and to the use of the river water.

3518 Q. Do you know of any typhoid fever among them since the opening of the canal?

A. There may have been some cases, but none to my knowl-
3519 edge.

Q. Into what place are the contents of the vaults and cesspools deposited?

A. In the current of the Kickapoo Creek near where it empties into the Illinois River.

Q. You may state how many permits were issued during your administration of the Health Department for the cleaning of such vaults and cesspools.

3522 A. About 750. * * *

Well, one thing I might explain, that the water is perhaps not as impure as we imagine.

Q. Now, you can go on and explain together your reasons for that explanation.

A. Well, we don't use the river water to any extent for drinking or domestic purposes, yet nearly all our ice is harvested from the Illinois River that is used in and around the city. This ice is used by hundreds of families for drinking purposes by putting the ice right into the water, and we don't find any bad results arising from
3527 that source.

W. A. McMILLAN,

Sanitary Officer, Health Department of Peoria.

The sewage from the vaults is deposited in the Kickapoo Creek and finally reaches the river.

3529 Number of vaults cleaned in the years '99 to 1902.

3530 EDWARD W. WOODRUFF,

Mayor, Peoria, and a dealer in natural ice.

Q. How many ice houses do you operate here?

A. Well, we have a capacity of 26,000 tons, divided into three locations along the river.

Q. What was the condition of the Illinois River water and the Illinois River before the opening of the drainage canal in January, 1900, as compared with the conditions that existed since the opening of the canal?

A. The water is better than it was, particularly since the opening of the canal; it is better than it was before.

Q. In what respect is it better?

A. Well, the water is clearer. Well, that practically is all—clearer and better condition in every way. I can possibly answer that

question better by saying that before the canal was turned in we were simply figuring on hunting other locations for ice cutting purposes, and I made investigations all through that part of the country where railroad rate was within reason, and wasn't able to find such location and concluded that it would possibly be better to manufacture ice, because we felt the time was coming when we would be shut out.

2533-34 Q. How many tons of ice taken from the Illinois River is sold to the consumers in Peoria by you?

A. Last year, as near as I can recollect, 19,000 or 20,000 tons.

Q. What, in your opinion, is the condition of the river to-day, as compared with the river before the opening of the drainage canal, as to the purity of the water?

A. The water is very much better, in my opinion.

CROSS-EXAMINATION.

Q. How many ice plants are there that take ice from the Illinois River, besides your own—not the artificial, I mean natural ice companies?

A. There are three dealers who sell ice in the city and two St. Louis who get the harvest ice above us.

Q. You cannot tell whether or not the impurities contained in the water have been increased by the addition of Chicago sewage, can you, except by its appearance?

A. The water is clearer for the reason that tools dropped in the water at a depth of four or five feet can be discerned and picked up, which could not have been done before the drainage canal

3537 was turned in.

Q. Mr. Mayor, I believe you stated that three St. Louis firms have been engaged in taking ice from Peoria Lake. Can you name those firms, and when they were engaged in taking ice from Peoria Lake?

A. I said two.

Q. Two, then; can you name them?

A. The Muckerman Ice & Coal Company, I think, is the style of one firm, and G. H. Donewald & Company, I think, are the others.

Q. When was that?

A. Last winter and I don't know how many winters before. A number of winters. Eight or ten or twelve.

Q. To what extent was there cutting and taking of ice, if you know?

3539 A. Combined, 12,000 to 14,000 tons.

ROBERT R. MARTIN, recalled:

Am acquainted with the river for the last fifteen or sixteen
3551 years.

I like to go out fishing and I like to eat fish. In the winter time, when the river would be frozen over, these fish caught above Peoria would have a tarrish, grassy taste, so much so that they were not fit to eat in the winter after the ice was frozen over for a short time. We have had no time that I could mention this winter but what we have had fish once or twice a week at our house, and they have not that taste now, where they used to have it before the canal came in. That is my judgment and opinion. We relish the fish as much in the winter now as in the summer.

Q. What, in your opinion, has been the effect of the drainage canal upon the water of the Illinois River?

A. I think it has given us a better river.

Q. Better water?

A. I don't know whether it has any effect upon the mosquitoes. In the last few years we have had less mosquitoes up here. I believe that is due to covering over the swamp land with water, the mosquito part.

3552 CROSS-EXAMINATION.

Q. You don't know anything about the effect of the sewage discharged from Chicago into the Illinois River, do you, upon the sanitary condition of that water, nor its appearance, but not its sanitary condition?

A. I will only say this: That if there is that much corruption coming down there they must give us good corruption for water and fish, for it has made it better. Fish are good to eat now, winter and summer. * * * They were rotten with a tarrish and grassy taste. In going out fishing I have taken a drink of this water now when real thirsty. Of course, I don't do that because I love any river water, but thirst—but I wouldn't do it before, because I knew what it was. I pumped it at the old pumping station, and I saw enough. * * *

Q. When you say the water is better, you judge simply from its appearance?

A. Well, I drink it.

Q. Without any reference to the properties it may contain?
3553 A. Only the properties and use of it and sight.

CHARLES F. HICKSON.

I run a summer resort and boat yard near the upper free bridge at a place called Sandy Bridge, above Peoria, and have been in that occupation eight years.

Q. What was the condition of the Illinois River above the place called the Narrows prior to the opening of the drainage canal?

A. Before the opening of the drainage canal, in the summer time, when the water was very low, the water became very foul and had a very bad odor to it, and there would come a very heavy green scum. Through the months of July and August, particularly, a man would get up at four o'clock or daylight, the odor that came from the river was something fearful.

Q. Do you know anything of its effect upon the fish?

A. Well, in the winter time the fish, when the river was froze over wasn't fit to eat. They had a peculiar tarrish, grassy taste. You couldn't eat them. Lots of them would die. In the spring, when the ice would break up, you would see thousands of dead fish floating in the river.

Q. Since the opening of the drainage canal, what has been the condition of the river above the Narrows?

A. It has been very much better. We have had a higher stage of water. The water has been purer to the naked eye and clearer, and we have not had that odor coming from the river that we had prior. We have had no trouble in regard to the fish since.

WILLIAM BAKER,

3557 Agent for the State Board Live Stock or Inspector at the United States Yards, Peoria, Illinois.

3561 The stock yards, I would say, is about two blocks wide and about four long, or about 1,000 feet wide and 3,000 feet long. They are divided into cattle pens and the hog division is floored with wooden floors. I would say roughly 6,000 hogs a week and from 300 to 600 cattle and probably 100 sheep pass through the yards a week, and each pen has a sewage or catch basin, and of course what is carried off in them, and what is not is hauled out of the pens. The pens are cleaned of offals of different kinds which passes into the sewers and from the sewers into the Illinois River.

3562 PERCY M. SWAIN,

Captain of the steamer Fred Swain, plying between Peoria and La Salle, and have been running on the river on other
3564 boats since 1892.

Q. Will you describe the condition of the river before the opening of the drainage canal in 1900?

A. Well, prior to the turning in of the drainage there was very little current and there was a green scum formed on the river and the water was not clear. The water had the appearance more of a kind of—in the lake here, a kind of white appearance more like sewage color, you know, and in places, for instance, the locks, there it had this greenness. It would also form on the gates and also formed on the boat, and this kind of a white stuff, and a considerable odor came from the water. For instance, Lacon, where there was much of a current, there would be an odor there, and also at the locks. In the winter time, when the water was frozen over, there was more or less dead fish, and where they took up the nets in fishing there was more or less odor, more than there is since the turning in of the drainage. The river is altogether different now than it was prior to the turning in of the drainage. * * * It is clearer and this green scum doesn't form any more, only in places, like, for instance, Lake Depew, or, for instance, the Illinois River, where there is no current. * * * Heretofore it was necessary to clean the boilers once a week every week, but of late once in two weeks is sufficient.

3566 Q. Do you observe any difference in the water above the Peoria bridge over the condition below the Peoria bridge?

A. Why, above the bridge the water is considerably different from the water below the bridge. Below the bridge, where it gets the sewage from stock yards and packing houses, it has a thick, mushy appearance. Two hundred or three hundred feet from land you can see this stuff bubble up before you, or within 200 or 300 feet of the shore. You can see this stuff bubble up. This stuff rises up in the bottom that way, a black appearance, an awful appearance, but we always stop the pumps from getting in there to keep from pumping this stuff into the boiler and causing the stopping of the pipes, and it has a kind of a rotten smell or odor coming off of it or odor, a kind of a rotten smell like. * * * It is a matter of knowledge with me. I have been there and seen it.

3567-3568 ALEXANDER RICHARDSON.

I have been in the jewelry business for a number of years and my trade was an engraver. Have lived in Peoria for over thirty years and have fished for thirty years annually and have hunted for fifteen or twenty.

3572 Q. What was the condition of the water in the Illinois River above Peoria before the opening of the drainage canal in January, 1900?

A. The condition of the water was very bad, extremely bad in my opinion. The water was very low at certain seasons of the year, summer, for instance, and at some points it was covered with a green scum clear across and above the city—you could smell it here—a very bad odor. I could not describe the odor any better than to say it was very obnoxious, disagreeable bad smell.

3573 Since the opening of the drainage canal it is virtually a new stream, you may say, it is so much improved. There has been so much larger volume of water and so much greater current that we find the water is purer, colder and better in every way. The fish are harder and firmer, and of a better flavor, and since the opening of the canal and the coming in of the water we catch larger fish, such as bass and pike, which we didn't catch before.

3574 MICHAEL D. HURLEY.

I am doing special work for the Fish Commissioner. Before that I was Captain of Police for two years in Peoria, and prior to that was a wholesale fish dealer for about seven years. I am acquainted with the whole river, but particularly from Havana to Henry, during the time I was in the fish business.

3576 I had on the fish crew and market between fifteen and seventeen men usually.

Q. What was the condition of the Illinois River prior to the opening of the drainage canal from Peoria to Havana and from Peoria to Henry?

A. Below Peoria, at a low stage of the water, it was muddy, mixed with manure, and what we used to call slop, when we were fishing in it, supposed to be from the sugar works, and the slop refuse from distilleries. It was generally pretty strong smelling when it was stirred and even when it wasn't stirred up it would smell pretty strong, that is, below Peoria. It would smell there somewhat different than it was above. * * * In Peoria Lake and the lakes above

here it was covered with a green scum during the warm season. The water itself looked green. It smelled badly with a different smell than below, but I couldn't tell exactly what the difference was, except it was noticeable. * * * There were times, both winter and summer, that the fish used to die in numbers. In the winter more particularly above Peoria, in the summer just from the distilleries on down.

3577 Passing boats would leave a wake or trail like behind through the green scum, which could be observed as far as the eye could reach generally, unless the river was choppy. Since the opening of the drainage canal there has been an absence of the scum and the smell has disappeared almost altogether except below the city proper here. The water was clearer apparently and better.

3578 Q. How does the condition of the water above Peoria compare with that at and below Peoria?

A. It seems clearer and better in every way, better looking river. * * * I have drank the water both before and after the drainage was turned in. * * * I have never heard of much, if any, sickness since the drainage was turned in, from drinking the water, while I know it was making them sick before it was

3579 turned in.

CROSS-EXAMINATION.

Q. The fact that the sewage is discharged into the Illinois River at Chicago has no effect upon your mind as to the sanitary condition of the water in the river below and at Peoria and above Peoria?

A. It has not, because I never had any ill effects come under my observation. * * * I only know of the ill effects before and know of none since. That is the particular reason why I paid no attention to the Chicago so-called sewage.

3582 Q. Well, didn't I understand you to say in that last answer that you knew of no ill effects either before or since?

A. My reason was the reason why I paid no particular attention to what they were saying of the Chicago sewage, and its effect was that I knew of ill effects before drainage was turned in and none since. Hence I gave no weight or thought in reference to the water being worse now. I think it is better.

CHARLES S. BARTSON.

I am in the saloon business, but formerly was in the wholesale fish business. Started in 1892 and sold out in 1900 and at that time

was personally engaged in taking fish from the Illinois River with nets, from five miles below the Copperas Creek Lock as far up as Chillicothe. * * * Before the opening of the drainage canal the water was a great deal lower than it is now. The conditions that exist down there now are as they did then in regard to fishing.

3583 Q. What are the conditions below here as to fishing as to the matter upon the nets and the condition of the fish and the water?

A. The matter upon the nets is a sort of a slime. I cannot say exactly what it is, but it accumulates upon your nets so that you have to wash the nets every day or two in order to fish successfully with nets. * * * Whenever we got a bad winter below Peoria it killed a great many of them (fish). In summer I have seen fish come to the top by hundreds; the gas killed them. When there was ice on the river they got so bad we couldn't use them. Since the

3584 opening of the drainage canal the character of the water in the river above Peoria has been good and I have not known of the fish dying on the ice since. * * * The fish live three or four times longer now than they did before in live boxes. Before the opening of the canal the water made me sick when I drank it, but since the opening of the canal the water has been better.

I have not known of any typhoid fever among the fishermen

2586 since the opening of the canal.

J. N. FEGER.

I am in the electric business. Have lived in Peoria thirty years and have fished on the river all my life with hook and line from Havana to Henry. Prior to the opening of the drainage canal I considered the water bad. It was scumy and green and sluggish and had an odor. Its effect on fish was very bad. They were very soft, I know, down here at Pekin; the city had to hire people to go and bury them. Since the opening of the drainage canal the water has been better, the condition of the fish better, and the water above Peoria has been better than the water below Peoria.

3589

R. R. BOURLAND.

I am in the real estate and loan business and am secretary of the Illinois River Valley Association, which association has existed since 1897.

3590 The Illinois River was an ordinary sluggish stream that was disagreeable in low water. * * * Below Peoria it was

very much infected by the drainage of Peoria and was a much more disagreeable stream below. * * * There was certainly an odor from below. I am not so positive as to the fact of the odor coming from above. I have frequently traveled the Illinois River above and below Peoria before and since 1900. Above Peoria it is certainly a great deal better now than it was before 1900. The water is clearer in color and does not get so low in low water, and therefore does not have disagreeable features of the former low stage of water. * * * Below Peoria the waters still show the effect of the offal from the factories, but not to the same extent as before, because of the greater volume of water, and I find the odor not nearly so apparent as it was before. * * *

3591 Before 1900 the use of the river for pleasure craft was almost entirely given up during low stages of water. Since that time there is continual use of the river by a great many people for pleasure purposes. I don't think that there were any houseboats, as they are called, on the river before 1900, and there are now quite a number which are used for summer residences by a number of people for mere pleasure.

3592 JOHN D. McCLURE.

I am in the real estate and loan business. Lived in Peoria fifty-three years. For fifty-three years I have been on the river every year a great many times, every summer fishing, and hunting.

3595 * * * Previous to the opening (of the drainage canal) it was at times very offensive, a green scum would form on it, and a stagnant, grassy smell to it, especially in low water, and when the ice was on the river, whenever we attempted to use the water, and my observation is that since the opening of the canal it has been very much improved. The water has been better, at least there is not so much of a smell, and not so much scum forms as there did before. * * * The water apparently seems purer.

3596 NAT H. COHEN.

I am president of the Illinois Fish Commission since 1897 and prior to that time was familiar with the Illinois River.

3597 I became acquainted with it by fishing in all the lakes from Havana to Meredosia. * * * In the spring, during the freshet I couldn't tell much difference in the water, but as the summer came on and the water receded from the banks the water became

stagnant, little or no current, covered with a green scum and a bad color. The lakes adjacent were low and a very high temperature, destroying fish from decayed aquatic matter, destroying what we term plantain. Plantain is the vegetable and animal life in the water, that the fry, the small fish, live on. The temperature becomes so high that they are all destroyed. * * * Since that time the same lakes, the temperature is much lower, the water much clearer,
3599-3600 and we find an absence of dead fish.

Q. What was the condition of the fish in the Illinois River above Peoria before the opening of the drainage canal?

A. Well, as a general thing the coloration was much lighter and they didn't have the tenacity of life that they have now. * * * Since the opening of the drainage canal I think the fish are
3600 much better, those that I have seen. * * * Before the opening of the drainage canal the condition of the Illinois
3601 River from Peoria to Pekin was very foul.

The water from Copperas Creek to La Grange was better than the water from Peoria to Pekin. * * * Before the opening of the drainage canal the water from La Grange and Kampsville Dam, I think, improved as it went down. Since the opening of the canal the water between Peoria and Copperas Creek is much better than it was prior to that.

3603 Q. Judging by its appearance and such superficial examination as you have made, which would you say was the better water, now, that between Peoria and Copperas Creek or that between La Salle and Kampsville?

A. I think that between La Salle and Kampsville is the best of the two.

Q. Since the opening of the drainage canal what has been the condition of the water of the Illinois River between Kampsville and Grafton?

A. Well, I cannot say anything about that any more than it
2604 improved as it went down.

Q. In your observation of the Illinois River, state whether or not the waters as they travel from source of impurities tend to purify themselves—seem to purify themselves?

A. Yes, they do, in my observation.

Q. Is there a large fishing industry on the Illinois River?

A. Yes, from 5,000 to 10,000 people employed on the river from La Salle to Grafton, and bringing into the state probably $500,000 and shipping out from 12,000,000 to 15,000,000 pounds of fish per annum. * * * From all the information I got along the

river they say there is less malaria and scarcely any typhoid fever among the fishermen for the last three years. They tell me
3607 they drink the water now and they couldn't drink it before.

CROSS-EXAMINATION.

Q. And not with reference to any particular purification or the absence of impurities in the water?

A. Well, you see, game fish will not live in anything but pure water, and they will not get the color they have unless the water is pure, that is to say, bass and light species.

Q. Do you mean chemically pure?

A. Well, I won't say that exactly, because I have never analyzed it or never had it analyzed, but from every observation I have had made bass won't thrive only in pure water, and if the water is foul and there is a spring close by you will always find the bass in the pure water.

3609 DR. FRANK C. BOURECHEIDT.

I was Health Commissioner from 1898 to 1904.

Q. Has there been any decrease or increase in the death rate from typhoid fever among those persons who resided on the immediate bank of the river or in houseboats on the river who use the water of the Illinois River?

A. I don't know of any case of that kind during my incumbency of office. I have not known of a case.

3611 CAPT. S. P. BARTLETT.

I am Fields Superintendent of the United States Fish Commission and have occupied that position about thirty-one years. I am also one of the Board of State Fish Commissioners and have served consecutively for twenty-four years.

3618 I have been intimately associated with the Illinois River for over thirty years.

Q. Prior to the opening of the drainage canal what was the character of the current of the Illinois River?

A. Well, that would depend upon the season of the year. In the early spring and after the snow and water had reached the river the current at times would probably reach a mile or a mile and a half an hour, of course being swifter at places. Later in the season when the water was lower it has been frequently impossible to tell

which way the current was going by an object on the surface. It was very sluggish, very slow.

3620 Q. Prior to the opening of the drainage canal what was the condition of the waters of the Illinois River between La Salle and Henry Dam?

A. Well, the water was about on the average of river water. In high water, reasonably clear; in low water there would be the incidental amount of vegetable growth and more or less impurities.

Q. Do you know whether prior to the opening of the drainage canal there was an odor in summer about the water of the Henry Dam?

A. Well, there was an odor more or less, as I remember it. It was given off as all low water does. It was from decaying

3621 and refuse matter dumped into it. * * *

I have seen the stage of water so low in the Illinois River during the winter season that the fish would perish under the ice during the winter. The ice becomes very thick and covers with a heavy blanket of snow; it stops the introduction or escape of any air, and the water, I think, becomes bad; it forms noxious gas under there, which is very destructive to fish and other life. The water becomes impure. * * *

I have known fish above Henry to die previous to the opening

3622 of the canal for many seasons. * * *

The strong fish always has a dark bright color. Since the opening of the drainage canal the condition of the Illinois River above Henry Dam, from personal observation of it, and going over it frequently, my judgment would be that the water shows a decided improvement in every way. Since the opening of the drainage canal I know of no complaint about fish. They are way up to the average. * * * It would be probably better to say that these vegetable growths are due, as a rule, to the outgrowth of low water and high temperature, and I have almost every season, when we have had a low stage of water, found a large amount of vegetable growth on the surface and moving upwards and forwards with the change of the wind. * * *

3623 Well, if there is in any way a large amount of it, and the water is very low, decomposition takes up a great deal of it, and a great deal of it is consumed by vegetable consuming fishes and aquatic birds. In very low water a great deal of it is left upon the shore and decomposes, which is frequently the cause of a great deal of bad odor. * * * Since the opening of the drainage canal the

Illinois River between Henry and Peoria—my observation has
3624 been that the water was very much better and clearer.

Q. At Peoria are there foreign substances deposited in the river, and if so from what source?

A. Yes, from all sources, the sewage, if very large, and the refuse from the gas house and distilleries and glucose factories is immense. * * *

Q. Below Peoria have you noticed this foreign matter in the water?

A. Yes, sir, in great quantities. * * * Principally the large deposit of offal from the distilleries and from the cattle pens breaking off, and falling into the river in large masses in the immense amount of sewage that collects at the river front during an east wind, driving it all on to the shore, or, rather, keeping it all on the shore, and particularly in the operation of the seine, in collecting the fish. We find a very heavy offensive deposit on all the shores along the river and the flat lakes adjoining. * * * The deposit looks like a great greasy substance, a slime I might call it, a very heavy slime. It is very offensive when brought to the surface. I am talking now about below Peoria. * * * I have met this condition frequently as far down as Havana, in limited quantities, of course. Havana is close to seventy miles below Peoria.

3625 This particular refuse from the gas works and distilleries and glucose factories is run off in spouts at the intake of the water and it is allowed to accumulate there, and when the very low water comes it breaks off and floats off with the current. That would be an impossibility if the stage of the water was of sufficient height to keep the shores clean. * * *

3626 If the river was rising and at such times this stuff would break off from the shores very easily, it was taken in great quantities into this lake (Spring Lake). In fact, I have seen it in bulk sufficient to absolutely prohibit the going in with our boats. We had to break it up before we could get by.

3627 I found the bottoms of those ponds frequently eight inches deep with this black slime, where there was only six or eight inches of water. * * * I took occasion to go over the grounds several times in later seasons and have found a very bad state of affairs there. Since the opening of the canal I have made a good many investigations of Spring Lake. * * * I have spent a good deal of time on the way looking after the conditions of the fish.

Q. Well, what has been the condition since the opening of the canal?

A. Well, again I will have to go back a little bit and make an explanation so you can understand the conditions. At that season of the year the weather was warm and the boat lay at Copperas Creek Dam, and I took occasion to make a critical examination of the number of black bass brought in by those who had been fishing on the lower end of Spring Lake, to satisfy myself as to the fish themselves. I found in a great many instances the fish very soft and took occasion to open them up, and found that the whole of the interior of the fish absolutely dissolved—from what cause I am not prepared to state, further than a few days later a great quantity of black bass were floating upon the water in the lower end of the lake and a post-mortem disclosed the same state of facts, that all of the digestive organs of the fish had been absolutely dissolved. The fish died, of course. I had no means of making an analytical examination of the liquid, but I am satisfied, as far as I could be from observation, that the cause of death was the very impure state of the water
3629-3630 at that time. * * *

Since the opening of the drainage canal I do not believe that there has been a season when any dead fish have been found upon the lake. My own particular observation of that locality is that the water is very much clearer, and a personal examination of the bottom, while it shows quite a deposit, is very slight as compared to the season of which I speak. * * *

3630 The condition has been that since the opening of the drainage canal of course there has been a very much greater volume of water. The water has been very much better. I have noticed a very great decrease in vegetation of various kinds. The best evidence that we have, if you will permit me to express it, of the increased betterment of the water at points below Copperas Creek, is the fact that there are more black bass in the river this year than I have ever known.

3631 Since the opening of the drainage canal between La Grange and Kampsville the condition of the water, in my opinion, has been good. The fish have been good, in fine condition. As I stated a moment ago, there are more black bass who are only habitats as a matter of choice of clear water. I am speaking of the river
3632 proper now.

From La Salle to Peoria, since the opening of the drainage canal, the water has improved until we get to Peoria Lake. From Peoria to Copperas Creek the water improves as you go down.

Q. Is the water in the Illinois River below Peoria and down to Copperas Creek better or worse than in Peoria Lake?

A. Well, I think the water below Peoria from Peoria to Copperas Creek Dam is worse than Peoria Lake considerably, very considerably, except under extraordinary conditions. There is rarely a better body of water found anywhere than in Peoria Lake.

Q. How does the water below Copperas Creek and down to La Grange Dam compare with the water above Copperas Creek?

A. I think it gets better all the time as you go further below. A great deal better. A MAN DOESN'T HAVE TO BE AN EXPERT TO NOTICE THAT. YOU CAN SEE THAT ALL THE TIME. THE CHARACTER OF WATER IS BETTER AS
3632 YOU GO DOWN.

3633 Description of the Illinois River in 1877.

I was aware that in 1885 the City of Chicago commenced to
3634 pump water into the Illinois and Michigan Canal.

My impression would be that there is anywhere from 2,500 to
3,500 people directly interested in fishing themselves. That doesn't include, however, the helpers. I am talking about the men
3635 who fish.

The number of people engaged in the preparation of the fish for market and the shipping of them after they are caught, including the fishermen themselves—I should think 5,000 would be a fair estimate.

Q. What was the condition of health of this class of men prior to the opening of the drainage canal as to typhoid fever and malarial fever and malarial diseases?

A. Well, I can only speak of that in a general way as to my own men particularly. We had a great deal of sickness. Not much typoid, but a great deal of very low grade fever. That, in my opinion—well, I was going to say as a physician, but from what knowledge I have of it, owing to a very bad state of the water during low water.

Q. Were you educated for a physician, and did you at one time practice medicine?

A. I never practiced medicine. I was educated and grad-
3635 uated as a physician. Too poor.

Q. Since the opening of the drainage canal what has been the condition of the health of the people engaged in business on the Illinois River in the fishing industry?

A. My observation has been that there has been a very great decrease in typhoid and intestinal diseases. * * * My work, as you know, carries me to almost every town along the Illinois River, and the natural tendency would be to talk over semi-professional

matters with physicians, and I believe with one single exception that every physician that I have talked to has commented on the decrease in typhoid and malarial fevers during the last two or three
3636 years.

Q. From all your sources of information of whatever character what has been the condition of the health of the fishermen on the Illinois River generally since the opening of the drainage canal, in your opinion?

A. Well, I should be inclined to say, from all sources of information, that it is a great deal better. My opinion is that there would be more than 5,000 people directly upon the river, that is to say, in tents or flatboats, and houseboats, and on the sloughs and bayous and bays, and lakes connected with the Illinois River.

Q. From all your sources of information and your personal knowledge since the opening of the drainage canal, what has been the condition of the health of that class of population since the opening of the drainage canal?

A. Why, in my opinion, the health has improved. That from
3637 all sources of information that I have been able to discover.

The growth of interest in fishing and sport on the Illinois River has been great, and almost every available lake on the river of any size has been taken up for pleasure resorts. Wherever they can put down a dry well, but in a great many places that I know of they are now using the water for drinking and domestic purposes. * * * The Illinois River is very peculiar in its formation, in that it has flat shores on both sides of the river. * * * These bottoms, extending from three to fifteen miles in width, and flat almost in every case, with lakes and sloughs aside from the river itself, as the fall is only one-half inch to the mile, the overflows are very frequent, and the lakes fill up and evaporate again several times during a season—during the dry seasons. The course of the river is inclined to be free from bars, and of very even depth. The land on both sides, of course, on account of frequent overflows, is very much as nature left if. * * * The river in extreme high water
3638 will be, of course, from bluff to bluff, frequently twelve to fifteen miles wide.

Q. Do you know whether domestic animals adjoining the river are accustomed to drink of its waters?

A. Oh, yes, all the time. * * * The lowlands above
3639 Havana particularly, and a great many other places, are used for pastures.

Q. Did you ever hear of a disease called anthrax among the cattle of Illinois River?

A. I have not among the cattle of Illinois River, no. I have heard of the disease.

Q. Do you know or did you ever hear of any disease among cattle drinking the water of the Illinois River which was attributed to the drinking of the water of the Illinois?

3640 A. No, sir.

Q. What is the extent of the fishing industry upon the Illinois River?

A. In 1901 the report of the fishermen's association, which comprises an organization of about 1,000 men on the Illinois River, gives as a total, of coarse fish caught nearly 18,000,000 pounds, with quite a percentage of fine fish added. The amount of money they reported as having received for their output, a little over three-quarters of a million dollars. This is simply reports from the books of the fishermen's association and submitted to me under oath.

3641 CROSS-EXAMINATION.

Q. This pollution that you speak of, captain, before the canal was opened, was it of vegetable character?

A. Well, I cannot tell you. When I speak of it I speak of such personal experience as I have had with it. A very large amount of the damage is due to the decomposition of vegetable matter. Below Peoria that is the worst. The greatest amount of damage is done, in my opinion, from the offal and refuse and whatever escapes from the sewers from these manufacturing institutions.

3649 Q. Do you know the exact character of the matter that is discharged from the distilleries, glucose factories and other industries?

A. Yes, sir, I say exact character. I know this, that all the manure and slop and general offal from the cattle pens is run down to the river through long chutes to the river edge. That is mixed up with a manure of some kind; what constitutes it I don't know, and that is deposited on the river bank, the fluid escaping. It dries out and that lays there until it hardens, and with any rise in the river it is either broken off by the rise in the river or by some artificial means and turned in and it floats down the river. That is the perceptible cause of a good deal of pollution. My own personal opinion is, however, that some of the most destructive elements come directly from the sewers of Peoria and from the gas houses.

Q. You know nothing of the condition of the water from a sanitary standpoint, other than what you have testified?

A. Well, I heard you say a while ago that you didn't care to go into expert testimony in that case. My investigations are all
3651 along that line, and I don't care to go into it unless you want me to.

WILLIAM H. BINNIAN,

President of the Acme Harvesting Company and the Peoria Strawboard Company.

I employ on an average of about 700 men. Have lived in
3641 Peoria forty-six years.

Before the opening of the drainage canal the Illinois River was a pretty filthy stream and quite sluggish. The river was very much more filthy below the city than above, on account of the refuse matter thrown in by the manufacturing plants on the river. Since the opening of the canal to all appearances it has cleared it up very materially and practically we have found that it has been a very great benefit; that is, particularly through the strawboard
3642 mill.

Q. What is your opinion as a manufacturer as to the quality of the Illinois River at present for manufacturing purposes and the use to which water is put in manufacturing?

A. Why, I am firmly convinced that it is far superior to-day to what it was prior to the opening of the drainage canal, by practical experience and scientific tests that have been made at both plants at times. * * * I don't think it can be excelled. It is a
3640 most excelent water for manufacturing purposes, for steaming purposes. We use about two and a half million gallons of
3645 water per day at the strawboard plant.

W. F. YORK.

I am a captain of a steamboat and have been steamboating since 1850 on the Illinois River, and am now engaged in running a steamboat on the river. Before the opening of the canal it was pretty sluggish and dirty. There was no current in it and a green scum on it. It didn't stir at all. It just lay around rotten and full of all kinds of insects. Since the opening of the drainage canal above Peoria I think it has been better than it was before the drainage canal was put in. * * * Better for steaming purposes. Below Peoria for steaming purposes it was very bad before the opening of the canal;

the boiler would foam, but since the opening of the canal it has been considerably better than it used to be. It has been purer and there has not been so much dirt in it.

3653 ISAAC TAYLOR.

I am in the real estate and loan business and have lived in Peoria for thirty-three years. Have been Canal Commissioner and also special commissioner to inspect Chicago drainage canal. I have been frequently on the Illinois River from La Salle to Copperas Creek. From 1850 to the present time. I am chairman of the Illinois Valley Association and have been most of the time since
3657 '87.

Q. Before the opening of the drainage canal, what was the character and quality of the water in the Illinois River?

A. When the river was low it was bad looking and bad smelling water, especially in the upper portions of the river.

Q. From what point to what point?

A. From La Salle—it was more noticeable from La Salle to Henry and it was also noticeable from Henry to Peoria, but not so much so.

Q. How was it from Peoria down?

A. It was in a bad condition. * * *

3659 When the water was low from Peoria down to Copperas Creek it was usually observed that the waters were of a dark character with considerable sediment in it. The opening of the drainage canal has made the water very much clearer and very much better. * * * The water immediately above Peoria in Lake Peoria is in a very good condition and there is no odor discernible. The water below Peoria is much better than formerly.

3660 E. M. WYATT.

I am on the Health Department at present and formerly an inspector at the stock yards at Peoria. The number of cattle passing through Peoria would average somewhere from 500 to 700 a month. Hogs from 15,000 to 25,000; very few sheep.

3650 The public slaughter house is situated a couple or three thou-
sand feet west of the river, the two packing houses about one
3667 and one-half blocks from the river, and the sewer into the river.

R. D. CLARK.

I am general manager of the Clark Bros. & Co., distillers. Have been in the distilling business since 1892. Am president of the Thomas & Clark Crockery Mfg. and president of the Peoria
3669-3670 Board of Trade.

Q. Do you know the average number of cattle fed in Peoria during the last ten years?

A. For the last five years they would average about 10,000, perhaps a little more.

Q. In the fattening of 10,000 head of cattle, what is the
3670 amount of salt used?

A. About five carloads of 140 barrels each.

Q. How does the water of the Illinois River compare to-day with what it did before the opening of the drainage canal in the manufacture of steam for mechanical uses of the water?

A. It is better for boiler purposes. * * * The boilers
3672 don't seem to have the tendency to foam that they used to have when pushed pretty hard.

Before the opening of the canal during high water it (the Illinois River) from Peoria to Henry was good, but a trifle muddy. During the low water stage there appeared a sort of a green scum which would form and bubble after the boat which I have not noticed of late. There was considerable odor at times. When the ice broke up it was very foul. I have seen thousands of dead fish along the river, but do not remember seeing them above upper Peoria bridge.

Q. How did the stretch of river from Peoria bridge to a distance half way between Peoria and Pekin compare with the same distance above Peoria prior to the opening of the drainage canal?

A. The river was considerably more dirty. It smelled a little
3674-75 different.

Q. How does it compare in average condition to-day with what it was before the opening of the canal?

A. It seems to be very much improved.

Q. How does the water become as you go down the river towards Copperas Creek Dam?

A. To Pekin it gets better. Below Pekin for a mile or two it is bad again, and by the time you reach Copperas Creek or even Spring Lake the water is in good condition.

Q. How does the general condition of the water in the Illinois River from Copperas Creek to Henry, taken in the condition that existed at Peoria and Pekin, compare to-day with the conditions that existed prior to the opening of the drainage canal?

A. It appears to me it is very much better.

Q. Do you know of any one that drinks the water of the Illinois River to-day?

3676 A. I have drank it myself.

Q. Do you know of any one who has gotten typhoid fever from drinking the water of the river since the opening of the canal?

A. No, sir.

Q. What is your opinion as to the general sanitary condition of the waters of the Illinois River at present as compared with before the opening of the canal?

A. I took it for granted it is better than it used to be from the absence of smell and color.

Q. Could the water be used to advantage in the mashing process at the distillery?

3677 A. I would just as soon have it as the other.

LOUIS P. BAUR,

3680 Superintendent of the Glucose Sugar Refining Company of Peoria, Illinois.

ADOLPH WOOLNER, JR.

I am manager of the Woolner Distillery Company and have been manager of the Atlas distillery for the past nine years. The capacity of that distillery was 7,500 bushels in twenty-four hours. Have been connected with the distillery business since 1880. Am familiar with the methods employed here in feeding cattle and have that cattle on my distillery. There have been as high as 40,000 head of cattle fed at Peoria, but I think that is more than seven years ago.

Q. What number of cattle are being fed now?

A. I should think in the neighborhood of 10,000 head now.

Q. How many head are fed in Pekin?

A. I am not positive, but I think between 5,000 and 8,000 head; I am not sure.

They are fed on the waste material from the distillery after the alcohol has been distilled and it is called distilled slop.

We generally aim to feed them about a bushel to the head.

3690 That would be about forty gallons.

I should judge it would weigh in the neighborhood of ten pounds to the gallon, which would be 400 pounds in twenty-four hours. Besides the slop, about ten or eleven pounds of hay and a small amount of salt.

Q. Do you know how many tons of excreta are destroyed by a steer in one year?

A. The only way I can get at it is this: A steer will gain in eight months' feeding very close on to 400 pounds. That is 240 days that they are on feed. During that 240 days he consumed 28,400 pounds of liquid and salt feed. As there is only 400 pounds gain on the steer the balance naturally must pass away from him.

Q. And for twelve months it would amount to what?

A. About 120,000 pounds; about sixty odd tons a year.

Q. And what would be the discharge from 40,000 head of cattle?

A. Well, it would be just forty times that amount. It would be 2,400,000 tons.

Q. That would represent the amount of excreta from 40,000 head of cattle, would it not?

A. About that.

Q. How many tons of excreta would come from 18,000 cattle?

3691 A. 1,080,000, about.

Q. How many from 10,000 cattle?

A. 600,000, about.

Q. What becomes of the excreta from the cattle?

A. It is run into the Illinois River.

Q. Has that always been the custom here?

A. Yes, sir.

Q. So that the amount of pollution from the cattle sheds of Peoria from 1887 to the present has varied from 2,400,000 tons, what 40,000 head of cattle were fed, and 600,000 tons, what 10,000 head of cattle were fed? Is that correct?

A. About that. * * * I think the water since (the open-

3692 ing of the canal) is some better for steam making purposes.

D. S. BROWN.

I am in the real estate and piano business. Was formerly a distiller in Peoria from '76 to '86.

Q. From 1876 to 1886 how many distilleries were in operation in Peoria?

A. I couldn't remember to a certainty. I think ten, possibly twelve, but I wouldn't be sure.

Prior to the opening of the drainage canal the water was very bad, very offensive. Since the opening of the canal the condition of the water is very good as compared with what it was before and as compared, I think, with other rivers. It is clearer, freer from the

sewage and has a better color and no odor, comparatively
3696 little odor.

SOLOMON YORK.

I am a licensed pilot and captain and have been for the last thirty-four years. I have boated since I was four years old. My father was a boatman before me and I have never done anything else but boated. For ten years prior to the opening of the drainage canal the Illinois River was bad; it was stagnant. There was a scum on it a good many times in dead low water, and at times the growth in it would take the wheels of the boat that was turning twenty-five or thirty revolutions a minute, till a kind of whiskers would grow on it. We called it a kind of a hair that long (indicating) would grow. I have seen it that long on the bucket about four or five inches. That would grow on the bucket and the hull of the boat would have moss or hair along on the side of the boat.

3704 It was very bad below Peoria on account of the sewage here. Take it from here to Havana down as far as Beardstown, you could see the offal from the distilleries here. We worked for a boat down here in front of the distilleries three or four years, down here digging that out, and starting it on down the river. Go into it with the wheel and dig it out. It would pile up there eight or ten feet high. Since the opening of the drainage canal the water below Peoria
3705 has been better.

J. F. VINCENT.

My business is manager of the Peoria stock yards. The stock yards company owns twenty-two acres altogether. Part of that is taken up for packing houses and other purposes of that kind. The stock yards drain into the sewers of the city, which empty into
3706 the Illinois River.

FRED KINSINGER.

I am manager of the American Spirits Mfg. Co. There are three distilleries connected with that company, the Monarch, the Great Western and the Atlas. The combined capacity of the three houses is 25,200 bushels a day. We feed only 4,000 head of cattle a day. The balance of the slops, we dry them and ship.

FRANK C. WHITE.

3710 I am a dealer in stock and feed cattle at the distilleries in Peoria. I feed at the Atlas distillery. Have been twenty years in the
3713 cattle feeding business.
During the last three years I have fed from 2,500 to 3,000
3714 cattle.

PROF. JOHN H. LONG.

3984 I am teacher of chemistry in the Northwestern University of Chicago for the last twenty-two years. Prior to that I taught in Weslayan University at Middletown, Connecticut, for seven years. I studied in the University of Kansas and in the German universities. Am a member of the American and Foreign Scientific Societies and am president of the American Chemical Society. For a number of years I was chemist of the Board of Health of Chicago and since 1885 have been chemist of the Illinois State Board of
3985 Health.
3986 Duties under the Illinois State Board of Health.
3987 Description of the Illinois and Michigan Canal.
3988 Condition of the Chicago River prior to 1884.
3991 Sewage system of the City of Chicago.
3991 Character of water pumped by the Illinois and Michigan Canal.
Peoria meeting in 1887 for deep waterway from Chicago to
3993 Mississippi River.
Investigations and chemical surveys of the Illinois River.
3995 First period in 1885.
Second period of examination of the river and canal water, 1886.
3996 Third investigation, 1886-1887.
3997 Fourth investigation, 1888.
Fifth investigation, sewer water in the neighborhood of Bridge-
3999 port.
Methods of chemical determination. Total solids. Suspended
4002-4003 matter. Nitrates. Chlorine.
4004-4005 Hardness of the water. Free amonia. Albuminoid ammonia.
4006 Oxygen consuming power.
Interpretation of chemical analyses and their sanitary signifi-
4007-4010 cance with reference to water.
4028 Table of averages for the summer of 1886.

Q. From those analyses, professor, what conclusions do you draw?

A. Those analyses show beyond any question a very marked destruction of organic matter in the flow between Bridgeport and Peoria showing the effect of what is called bacterial oxidation in an extremely marked degree, the water at Peoria in that particular season being practically potable and naturally used by a large number of the people. I was at Peoria during the season and observed
4029 that fact myself.

4030 Table of summaries for the winter of 1886 and 1887.

Q. What conclusions do you draw from these averages for the winter of 1886 and 1887?

A. The conclusions that in the winter of 1886 and 1887, as in the summer of 1886, there is a very considerable destruction of organic matter in this stretch between Bridgeport and Peoria, but the destruction or oxidation is much less marked and characteristic than in the summer, as is always the case in these observa-
4031 tions.

4032 Table of summaries for the summer of 1888.

4033 Table of 1888 and 1889.

Q. What conclusions do you draw from those two tables of summaries, Professor?

A. These results show a purification of the river between the source of the water at Bridgeport and the outlet of the Illinois River at Grafton. The purification measured by the destruction of organic matter showed a very great or a very marked diminution of the organic matter. This diminution of the organic matter is due to two principal factors, the dilution of the stream by the water from various tributaries and to the destruction of the organic matter by the oxidation, using that term in a general sense or broad sense. The disappearance of organic matter is very much more marked than is the dilution as indicated by the change in chlorines, the condition being finally reached in which the organic matters are not larger
4040 or greater in amount than in the tributary streams.

Analyses were made in connection with this investigation of the waters of the tributaries of the Illinois River. Tables of such analyses appear on pages 4043-4071.

Q. Professor, from the summary of the analyses of 1888, based upon the analytical table contained in State of Illinois Exhibit A and the table of analyses of the Du Page, Kankakee, Fox, Big Vermillion, Little Vermillion, will you state what conclusions you draw from this table of analyses of the tributaries of the Illinois River and the table

of averages from the analyses made by you for the different points along the Illinois River?

A. The consideration of these tables which have been referred to, and given by me, and a comparison of the results of the analyses of the Illinois River at its mouth with the results of the analyses of the tributaries of the Illinois, indicate that a condition of organic purification of the Illinois at its mouth has been reached which is comparable with or similar to that found in the tributaries mentioned. As indicated by the various tests which have been described, the organic matters in the Illinois River have been reduced to a point where they are not larger in general than the organic matters found in the several tributaries. They have been reduced to a point beyond which the destruction of the organic matter in the river by natural means cannot practically be exceeded or surpassed. Apparently the limit of the oxidation of the organic matters has been reached. We have had condition in which the organic matters have been broken down and destroyed largely, and the residues that are left, not destroyed, are of a stable type, very resistent to the oxidizing influences, a condition characteristic of organic matter or vegetable rather than of animal origin, from which I conclude that in general these organic matters must be attributed to the leechings of the soil, that is, to products of vegetable origin, rather than to the products of animal origin. This condition obtains in all rivers to some extent and

4072 in the Illinois River at its mouth, and its tributaries. * * *

The organic matter in the Illinois River at points far above its mouth is in general larger than the organic matter in most of its tributaries, but by the time the mouth of the river has been reached the organic matter has become so far reduced that it compares in general very closely with that found in the tributaries and

4073 does not exceed that in the tributaries in general.

Table of comparisons of free ammonia, albuminoid ammonia

4074 and oxygen consumed for the Illinois River and its tributaries.

4076 Personal acquaintanceship with the river described in full.

Q. Professor, have you the table of analyses made by you in the winter of 1888 and 1889?

A. I have.*

Q. From that table of analyses, what conclusions, if any, do you draw?

A. This table, giving the summary of the analyses made during the winter of 1888 and 1889, shows a considerable reduction of the water contaminations of the water between Bridgeport and Grafton.

* They have already been read in evidence.

but a very much less marked degree of reduction than was observed in the summer of 1888. * * * While in the summer work the amount of organic matter in the river at Pekin, as disclosed by the analyses, does not appear to be extensive, at any rate no very great increase is detected there during the winter of 1888 and 1889; these factors show especially as regards the undecomposed nitrogenous substances indicated by the albuminoid ammonia, a very large residuant. * * *

During the summer season in the stretch between Peoria and Pekin, which is a nearly level stretch of eight or ten miles in extent, an enormous decomposition of organic matter occurs, as is observable in passing through the stream. * * * In the winter season, therefore, we have this rate very much slower, so that at Pekin, below the distilleries and cattle sheds of Peoria, enormous pollution, as indicated by the residua albuminoid ammonia and the factor for oxygen consumption, indicates fresh and recent additions. The consideration of these facts show beyond any question whatever that the addition of filth at Peoria is a very important factor in accounting
4079-4081 for the organic matter in the river below.

4082 I had personal knowledge of the sewage conditions at Peoria.

4095 Examinations of the sewers of Chicago in 1890 and 1891.

I found at that time that the organic matter which was discharged from the city and stock yards sewers in the neighborhood of Bridgeport pumps amounted to approximately 240
4097 tons daily.

Q. Professor, from your examinations, as you have testified from 1886 down to the winter of 1888 and 1889, exclusive of the sewage examinations at Chicago made by you and testified to by you in the record, what did these examinations disclose as to the conditions of the Illinois River for these separate periods?

A. The comparison of the results obtained for the Illinois in 1886 with those obtained in the years later, 1888 and 1889, indicates increased pollution of the Illinois River at Peoria. From personal observation of the Illinois River at Peoria in 1886 I know that the water was potable and formed a large part of the water supply of the City of Peoria. From personal observation I know that later this water supply was abandoned because of the increasing pollu-
4099 tion of the river, which was shown also by the analyses.

4100 The Herring commission and what led to its appointment.

Q. Did you make any series of analyses in the year 1899?

A. I did.

In the summer of 1889 ('99) I was authorized by the State

Board of Health to begin a chemical examination of the waters of the Illinois River and its tributaries and the canal leading from
4104 Chicago into the Illinois River. * * *
4104-4105 Points of collection.
4108 Points in tributaries.

Q. Did you make an investigation in 1900?

A. I did. Samples were collected at the same points during 1899 with two exceptions to be mentioned; the collection be-
4108 ing made by the same collectors.

Q. Did you make an investigation in 1901?

A. I did. * * *

Q. At what points were the samples collected in 1901?

A. IN 1901 SAMPLES WERE COLLECTED AT THE MOUTH OF THE ILLINOIS RIVER AT GRAFTON, THE MISSISSIPPI RIVER AT GRAFTON, THE COLLECTOR BEING MR. F. M. CALHOUN, THE COLLECTOR IN THE PREVIOUS INVESTIGATION. SAMPLES WERE ALSO TAKEN FROM THE MOUTH OF THE MISSOURI RIVER AT A POINT ABOUT 200 YARDS ABOVE ITS JUNCTION WITH THE MISSISSIPPI, THE COLLECTOR THERE BEING MR. GUS
4109 BAILEY.

Cards of witness F. M. Calhoun at Grafton and three separate exhibits for Mississippi River and Illinois River marked "State of Illinois, No. 1, 2 and 3" for identification; cards of witness G. Bailey at mouth of Missouri River and marked "State of Illinois, No.
4115-4116 4," for identification.

After the arrival of the bacilli sample at the laboratory certain tests of a chemical nature, sometimes spoken of as bacterial, were made by myself. The portion of water from the small bottle being used for this purpose and being taken in such a manner as not to interfere with the use of the remainder for the bacilli test proper. The remainder of this sample was then turned over to Dr. Robert F. Zeit for examination. The bacilli samples were all handled under my immediate direction or supervision or by myself or Mr. Wright or Mr. Johnson referred to. The experiments made by them were made under my supervision, handled simply for me and with me.

Q. And the remainder of the sample was turned over to Professor Zeit, as you stated?

A. Turned over to Professor Zeit by myself as I have stated. Professor Zeit's laboratory being in the same building and on
4119-4120 the same floor.

In these later investigations a test was made for the substances
4121 known as nitrites.

4121 Number of samples analyzed in 1899 at different places.
4125-4126-4127 Bacterial chemical examination of water as made by Professor Long and technique of same.
4129-4157 Tables of examination for 1899.
4159 Table of averages for 1899.

Q. From a consideration of these tables of analyses as introduced by you and the table of averages drawn from these tables of analyses, what conclusions do you draw as to the waters of the Illinois River?

A. From a consideration of the tables present and from the tables of averages drawn from these individual tables, these general conclusions may be reached: First, That the first and most general examination ofthis table shows a very great diminution in the organic pollution of the Illinois River, its tributaries and the sources between Bridgeport and upper Peoria, or Averyville, a diminution of the organic matter which cannot be accounted for by the dilution from the tributary waters as shown approximately by the decrease in the chlorine contents. This decrease in organic matter is explained by a consideration of several factors. We find in considering the data given for oxygen absorption, or oxygen consumption in the filtered water, as well as in the unfiltered water, that between Bridgeport and Peoria there is a very marked decrease, a point being reached finally where the organic matter as disclosed by the oxygen consumption test does not appreciably differ from that found in the tributaries of the Illinois as shown by the same test. I find also a very marked decrease in the amount of the product indicated by the albuminoid ammonia, a decrease of from three parts per million to .57 parts per million, this last amount being not a great deal different from that found in several of the tributaries of the Illinois. I find also in considering this table a very marked change in the decrease in the amount of the so-called free ammonia, the decrease here being very nearly from twenty parts per million to less than one part per million, this decrease being in a measure an index to the extent of bacterial oxidation or purification which has taken place in this part of the stream. We observe also that figures show the amount of nitrogen present in the form of nitrates, for a very great amount of oxidation has taken place in the Illinois River, the nitrates resulting from the bacterial oxidation of the nitrogen which has previously existed in some other forms, and which has gone through the stage of free ammonia. We observe also the appearance of nitrates in considerable amounts in the lower stretch of this part of the river, the nitrates indicating also the advance of oxidation. A very noticable feature of these tables is that after

Upper Peoria or Averyville or the Peoria Narrows is passed the condition of the river, as disclosed by the analyses, shows a very marked organic pollution again. We find that below Peoria the amount of organic pollution, as measured by the albuminod ammonia, is very nearly as great as that observed in the canal at Bridgeport. We find also in passing Peoria that the free ammonia has increased from less than one part per million to over four parts per million. We find also that the figures measuring the oxygen consumption in passing Peoria have increased in the case of the unfiltered water from over six parts per million to over seventeen parts per million, and the figure indicating the oxygen consumption in the filtered water has increased approximately from five and one-half parts per million to nearly thirteen parts per million. This remarkable increase in the numbers given shows that at this point a very great amount of organic matter has been added to the Illinois River. From the investigations which I have myself made at different times, an explanation of this increase is given. It is a matter of personal investigation and also of common knowledge that in the City of Peoria there are great industries which discharge wastes of a highly organic nature into the Illinois River, and the samples of water collected at Wesley were taken at a point below the discharge of these industries. These industrial wastes are mainly from distilleries and from cattle sheds in which cattle feeding on the slops of these distilleries are kept and from glucose factories. Coming down the river from Peoria, we observe again, as we did in coming down from Bridgeport to Peoria, a very marked gradual decrease in organic contamination. This decrease is observed in a gradual fall in the figures, indicating the oxygen consumption in the filtered and unfiltered water, and in the free ammonia and in the albuminoid ammonia, so that a change takes place in the Illinois River below Peoria and is due to the same general causes as indicated by the amount and character of the products given here, as takes place in the river above Peoria, so that finally at the mouth of the river at Grafton we have reached a condition in which the factors for organic pollution are not greatly different or essentially different from those observed in the tributaries of the Illinois River. Taken as a whole then, these tables disclose two main sources of contamination of the Illinois River; first, the sewage from the City of Chicago, which decreases very greatly before Peoria is reached, and, secondly, the industrial wastes from the City of Peoria, which decrease greatly before the mouth of the river at Grafton is reached. A consideration of these figures shows beyond any question that the main factor in the contamination of the Illinois River at its mouth is

not the waste or sewage contributed at Chicago, but the industrial waste contributed from the various industries in the City of
4160-4161-4162 Peoria.

A comparison of the Desplaines River at Joliet with the water
4163-4164 of the Illinois River at Wesley for 1899.

Comparison of the Illinois River at Peoria Narrows with the
4165 Fox River at Ottawa.

Comparison of the Illinois at La Salle with the condition of
4165 the water at Pekin, Illinois.

Q. How does the condition of the water at Peoria Narrows compare with the waters of the Illinois River at Grafton?

A. In comparing the waters of the Illinois River at Peoria and the Peoria Narrows and Grafton, we find, as measured by the oxygen consumption figures, by the free and albuminoid ammonia figures, somewhat more organic matter indicated at Peoria than at Grafton, but not a great deal more.

Q. How do the waters at the Narrows compare with the water of the Mississippi River at Grafton for this period?

A. As indicated by the oxygen consumption test, the Mississippi River water at Grafton contains more organic matter than the Illinois River water at Peoria Narrows. As indicated by the figures for free ammonia oxidation has gone very much further in the Mississippi River at Grafton than in the Narrows at Peoria. As indicated by the albuminoid ammonia test, the organic matter in the Mississippi River at Grafton is about 80 per cent. of that in the Illinois River at the Peoria Narrows.

Q. How does the water of the Illinois River at Grafton compare with the Mississippi River at Grafton?

A. As measured by the oxygen consumption test the Mississippi River water at Grafton contains more organic matter than the Illinois River water at Grafton. As measured by the albuminoid ammonia, the Illinois River at Grafton resembles very closely the Mississippi River water at Grafton.

4166 Desplaines River.

Q. Have you made analyses of the Desplaines River water at Lockport?

A. I have.

Q. Are you acquainted with the Desplaines River above that point?

A. I am.

Q. Will you give the extent of your personal acquaintanceship with the river?

A. I am familiar with the Desplaines River from the point where it joins with the canal near Joliet, above Joliet, to a point many miles north of Chicago, where the river flows out from a certain swampy region. The Desplaines River is a sluggish stream which drains a number of suburban towns around Chicago; the town of Riverside, the town of La Grange, Maywood and Norwood Park drain into the Desplaines.

Q. Do your analyses show that that river would be a safe and potable river or that the water of that river would be safe and potable for drinking purposes at that point?

A. I should not consider from these analyses that the water is a safe and potable water.

Q. From your analyses and from your present knowledge of the Desplaines River above Lockport, and from the towns that empty their sewage into the Chicago River, would you consider that a safe and potable river?

4167-4168 A. I would not.

Q. What does the bacterial result, such as you explained that you made this morning, disclose as to quality and condition of the water of the Illinois River and its tributaries?

A. These bacterial chemical results agree in a general way with the chemical results in showing the condition of extreme organic contamination at Bridgeport, Lockport and Joliet, which shows gradual improvement as we go down the river until Peoria is reached. Upper Peoria, or the Narrows, or Averyville, as it is called, where the individual results obtained by the various methods which I referred to this morning, do not differ essentially from similar results obtained from the tributaries of the Illinois, but leaving Peoria Narrows and going down to Wesley, we find, as indicated by these bacterial chemical results, great and marked increases of contamination again. The number of forms of organic matter in the organized condition or living condition at lower Peoria, or Wesley, as disclosed by what is called the colony count, is certainly as great as that found at Bridgeport, while the factors indicating the fermentation of carbo-hydrates by the bacteria present, and indicating the presence of these bacteria which convert carbo-hydrates into acids, and coagulate milk, are otherwise as great at Peoria as at Bridgeport. So these bacterial results then in general agree with the chemical results in showing an enormous increase of pollution as Peoria is passed, and these chemical bacterial results show, as we leave Peoria and go down the river, a gradual diminution in the organized forms until the mouth of the river is reached at Grafton, where the number of bacteria present

and the behavior of the bacteria with the reactions mentioned show a
condition similar to that found in many of the tributaries of
4169-4170 the Illinois.

Table for 1900, made shortly after the drainage canal was
4171-4180 opened in the spring of 1900.

Table of averages for the spring work, 1900.

4180 (Explanation of analytical tables and tables of averages.)

From these various tables I note that the amount of organic matter at Bridgeport in the old canal and the drainage canal at Western avenue is less than disclosed by the previous analyses given in 1899. An exact comparison is, however, difficult, because of the fact that in this period in the spring of 1900, the water flowed through both canals, through the Illinois and Michigan canal, but not at a constant rate, so that an exact comparison of these figures is difficult. However, as we proceed down the river to Morris, where there is a complete mixing of the waters, we find for the numbers representing the free and albuminoid ammonia, a lower amount than disclosed in the analyses made in 1899. When lower Peoria or Wesley is reached there is here a very great increase in the figures for all constituents. In the factor representing the oxygen absorption the free ammonia and the albuminoid ammonia, the decrease is very marked. Following below Peoria, we observe a decrease in these factors representing or pointing to the amount of organic matter present. We find at Pearl that the factors for oxygen consumption and for albuminoid ammonia are as low as in the 1899 examinations in general and as low as disclosed in the waters of many of the tributaries of the Illinois. We find at Grafton, however, below Pearl, for some reason which cannot be given, a slightly larger amount of organic matter in the mean, than at Pearl, but the point of greatest importance in this table is the very marked increase of the organic matter at Peoria and at
Wesley, the point below Peoria, as compared with the amount
4181 found at points above during this same examination.

Comparison of the Illinois River at Morris with the Illinois River at Wesley, immediately below Peoria.

A comparison between the waters at these points is a fair one, because they were collected through the same months and show this, that at Wesley, below Peoria, the organic matter, as measured by the oxygen absorption and by the albuminoid ammonia, and as indicated also by the results of the bacterial chemical examinations, is greater than that found in Morris through the same period. Any increased dilution below Morris would tend to decrease rather than increase the contamination at Peoria, making it appear even more strongly. The

organic matter is larger than at Morris. * * * At Grafton the various factors given in the table show a lower condition of contamination than at Morris in practically all cases. * * * At Morris, in 1900, after the opening of the drainage canal, the amount of albuminoid ammonia is very much less than the amount found in 1899 before the opening of the drainage canal. The factor for oxidation consumption in 1899, in the filtered water, is somewhat greater than for the filtered water in 1900, but for the unfiltered water slightly less. * * * I will say that the amount of organic matter present in 1900 is less than that present in the same volume in 1899. That indicates simply, as stated, that the amount of organic matter is less one year than the other, to make that direct comparison.

4182 * * * At Wesley in 1899, in the mean as indicated by the albuminoid ammonia there was more organic matter present than in 1900, as indicated by the oxygen consumption; also somewhat more in 1899 than in 1900. The free ammonia at Wesley in 1899 is greater than that at Wesley in 1900. * * * At Havana, in

4183 1899, the amount of organic matter, as measured in parts per million by the free and albuminoid ammonia, was greater than in 1900, and the oxygen consumed shows a somewhat smaller condition. The oxygen consumed is a little greater in the spring of 1900 than in 1899. As measured by the albuminoid ammonia in a given volume of the water, the analyses showed that there is a greater pollution in 1899 than in 1900, while as measured by the oxygen consumption the result from 1900 appears to be slightly greater than the results from 1899. * * * Comparing the river through the summer of 1899 at Grafton with that at Grafton through the spring of 1900, we find that the condition at Grafton shows more organic

4183 matter from a given volume in 1900 than it does in 1899. This comparison, however, is made between the rivers at the time of high floods in the second year and through the summer conditions in the first year.

The number of samples taken and the place where taken in

4185 the spring of 1900.

4186-4205 Tables for the summer analyses of 1900.

4207 Table of averages for the summer of 1900.

Number and places where samples were taken for the summer

4207-4208 of 1900.

Explanation of tables and averages for the summer of 1900.

These tables, considered in comparison with each other and in consideration of the averages of the table for the work for the summer of 1900, show, in general, to begin with, a lower initial con-

tamination of the water at Bridgeport than was the case in the examination of the waters made in the previous year, 1899. * * * As we proceed down the Illinois River proper, a gradual and continuous diminution in the factors indicating the organic contamination and to an extent which is very much greater than can be accounted for in any way by the amount of dilution coming in from the tributaries. * * * We find, also, * * * after Peoria Narrows is passed * * * a remarkable increase in the organic pollution again. * * * Below Peoria, as we proceed down the river, we observe a decrease again in these figures. * * * At the points below Pekin there is but little further decrease in the albuminoid ammonia which is comparable with that found in the ordinary rivers of the state. * * * Below Pekin there is a general gradual decrease until Grafton is reached, where the figures for oxygen consumption again have sunk to a point corresponding to those given for the 4209-4212 water of the tributaries entering the Illinois. * * *

Chlorine chart for chlorine between Bridgeport and Grafton
4214 for the summer of 1900.

4217 Free ammonia chart.

4220 Albuminoid ammonia curve.

4222 Oxygen consumed curve.

Q. Professor, state your general conclusions from the work of the summer of 1900 as shown by the tables and charts offered in evidence as to the character of the waters of the Illinois River and its tributaries.

A. A consideration of all the tables presented and of all the charts drawn from them, leads to this important and necessary conclusion, that in the flow of the sewage water from the pumps at Bridgeport through the drainage canal, and subsequently into and through the river, there is a very remarkable reduction or destruction of organic matter to Peoria, a great increase again between Peoria and Pekin, beyond which the reduction follows, which continues to the mouth of the Illinois River; as far as the organic conditions are concerned, the Illinois River is not more contaminated than are the ordinary tributaries and the rivers of this region flowing through a soil which contains large organic matter, and, finally, and the most important conclusion to be drawn from these tables and charts is, that the main factor in contamination of the Illinois River, is the addition of sewage from stock yards and distillery wastes
4225-4226 of the City of Peoria.

Q. Professor, did you make any chemical survey in 1901 and in the spring of 1902?

A. I did, in the Illinois River above Grafton, in the Mississippi River above Grafton, and the Missouri River above the mouth of that river, or the point where it flows into the Mississippi. This investigation was made in 1901, between September and the middle of December, and in the spring of 1902, through part of February and March, the samples were so taken, and the cards and tickets

4227 describing the location, etc., have already been introduced.

4230 Table for the mouth of the Illinois River.

4232 Table, Mississippi River above Grafton.

4234 Table, mouth of Missouri River.

Tables mouth of the Illinois River at Grafton, Mississippi

4236 River above Grafton, mouth of the Missouri River.

4239 Table of averages.

Q. From this table of averages, what conclusions do you draw as to the relative pollution of the Illinois River above Grafton, the Mississippi River above Grafton, and the Missouri River 600 feet above its mouth?

A. From a consideration of these several tables I draw the following general conclusion, that the organic condition of the Illinois River above Grafton is very much better than the organic con-

4239 dition of the Mississippi River above its mouth. * * *

Considering the chemical reactions due to the living organic matters in the Illinois and Missouri Rivers it is evident that the condition of the Illinois River is greatly superior to that of the Missouri throughout the whole period. * * * From the information obtained from the tests for the presence of these organisms, which have the power of breaking down carbo-hydrates, with the liberation of acids, which subsequently coagulates milk, it is likewise true that the contamination in the Missouri River is very much greater than the contamination in the Illinois River, through the same periods, the number of acid forming organisms, as disclosed by the results of the tests, being greater in the Missouri than in the Illinois. It also appears by a comparison of the tables in which a determination of a number of organisms was made by the so-called colony count process, that the Missouri River shows a greater contamination than does the Illinois through the same period. * * * The Illinois River is as pure as the Mississippi at the point of the junction of the Illinois with the Mississippi and the Illinois River is much purer than the Missouri at the point where the Missouri flows into the Missis-

4240 sippi. * * *

It is beyond question true that at the period of this investiga-

tion the Illinois River at its mouth was a much less contami-
4241 nated stream than the Missouri River at its mouth.

KAW RIVER.

I have examined the waters of the Kaw and Missouri River. I am familiar with the Kaw at its mouth for a distance of 100
4244 miles or more west. I lived for a number of years on the Kaw, and have been on it at numerous points.

Volume of flow of Kaw from May 24th to May 28th.

4245 Volume of flow of the Missouri River from May 22d to May 28th.

4245 Table of chlorine determinations of the Kaw River one and one-half miles above Kansas City.

Table of chlorine in the Missouri River above Kansas City.

Table of chlorine of the Missouri River below mouth of Kaw.

4246 Table for Missouri River below Kansas City.

General Averages. Chlorine.

Kaw River one and one-half miles above Kansas City 9.71.

Missouri River above Kansas City, general average 10.67.

Missouri River below mouth of the Kaw, general average 10.97.

4246 Missouri River below Kansas City, general average 12.31.

The averages drawn from these tables show a considerably larger figure for chlorine below Kansas City than in the Kaw or in
4247 the Missouri above Kansas City, being more than can be accounted for by any addition from the Kaw, and showing the fact that a certain proportion must come from the stock-yards industries and the sewers of Kansas City.

Q. Can the chlorines in the Missouri River be accounted for as being attributed to the Kaw River at the mouth of the Missouri River?

A. The chlorine at the mouth of the Missouri River can be attributed only in part to the chlorine of the Kaw River, the
4248 tables showing that the additions from Kansas City are an important factor. * * *

From all the examinations I have made of the Illinois River and its tributaries, it is my opinion that no part of the original organic matter leaving Chicago through the sanitary canal, and finding its way into the Illinois, reach the mouth of the Illinois River.
4250 and much less the intake tower of the St. Louis waterworks. * * * It is my belief that the sanitary condition of the water-supply of St. Louis is not and cannot be injured by any pollu-

tion passing through the drainage canal from Chicago to the Illinois River and down.

4251 Effect of flood periods in the Illinois River.

The Mississippi River was not at any near period a suitable river for household uses (at the chain of rocks).

Because of the addition of a large volume of Lake Michigan water to the canal, water flowing down the Illinois, and because further, the increase in the amount of pure water is very much in excess of the increase of the amount of sewage carried at the same time, the resultant effect is produced that the mouth of the

4254 Illinois River today is in a far better sanitary condition than obtained before the drainage canal opened.

Taking into consideration all the conditions which have been supposed, and especially the condition of the increased pollution, I am still of the opinion that the sanitary condition of the water of the Illinois River at its mouth has been improved instead of injured by the increased flow through the drainage canal. * * * Beyond all question, the sanitary condition of the Illinois River at its mouth is far superior to the Missouri River at its mouth, and not greatly different to the condition of the Mississippi River at a point where the Illinois and Mississippi Rivers unite. * * * As I stated

4255 in my previous testimony, I believe the effect of the Chicago sewage is completely lost before the mouth of the Illinois River is reached, and therefore cannot be a factor in determining any pollution in the Mississippi or Missouri Rivers.

Q. Assume that the waters of the Illinois River in 1902 were emptied directly into the Missouri River at its mouth, before the Missouri River enters the Mississippi, or before the Illinois empties into the Mississippi, would the waters of the Illinois River pollute the waters of the Missouri River?

A. No; on the contrary, the water of the Missouri would contaminate the water of the Illinois, the water of the Illinois

4256 being in a purer and better sanitary condition at that time than the water of the Missouri.

4256 Prodigiosus hypothetical questions.

4258-4259-4260 Answer to hypothetical question.

CROSS-EXAMINATION.

Q. Now, will you explain just how it was you made use of these bacteriological tests in your regular practice of the sanitary analyses of water?

A. In my examination of water I have made no attempt whatever to go into the question of the identification of bacteria. That is a field calling for the work of a specialist in bacteriology, but inasmuch as certain changes or reactions of a purely chemical nature are brought about by bacteria. I have given some attention to the conditions of such actions. Those are properly of a chemical rather than of a bacteriological nature. Certain bacteria have the power of producing certain decompositions which can also be produced by chemical means. For example, the decomposition of protein matters by bacteria are analogous in many cases to those by chemical
4263 reactions, and in such examination as I have made I have confined my attention to these reactions in using what are sometimes called bacteriological methods in water analysis.

Q. Were the bacterial chemical tests that you made sufficient to draw conclusions based upon a bacterial knowledge of water. * * *

A. In some cases that I now recall the evidence of the bacteriological examinations is sufficiently definite to lead to a definite conclusion without appeal to the results of the chemical analysis. * * *

Q. Now, will you state some of these instances?

A. For example, in comparing the Missouri with the Illinois
4265 River in 1901, where the bacterial evidence is very strong, that the Missouri River is a more contaminated stream than the Illinois.

Q. You are not a bacteriologist at all?

A. I am not a bacteriologist at all, and I can answer no question involving bacteriological knowledge.

Q. Well, how can you judge as to the character of the water from a sanitary standpoint, not being able to tell from a chemical bacterial test of the character of the pollution?

A. The character of the pollution, that can be answered in a
4266 very simple manner. I do not consider any river water receiving organic matter or drainage of farms or towns as at all suitable for drinking purposes directly. That is a general answer for that.

Q. Now, from these chemical bacterial tests, how can you determine the origin of the bacteria?

A. There is no way of always determining sharply the origin of the bacteria, but where enormously great numbers are found
4268 in sewage products, from the known facts regarding the production of these substances, the conclusion is in general warranted as to where they come from.

Q. Professor, how long a time is ordinarily taken for the sewage of Chicago to flow through the pipes from its source into the Chicago River?

A. I have no data at hand from which I could answer that question. In general, this statement can be made as a fair one, that because of the flat character of the City of Chicago the time
4277 consumed in the flow of sewage through the sewers is comparatively large, as compared with the time in most of our American cities. The sewage remains a comparatively long time in most of the sewers.

At times there has been apparently a very considerable increase in these factors, and false conclusions have been drawn from observation made at those times. It is now well known that there have been several periods when the water was assumed to come through the tunnels when it was pumped from very near the shore. For example, in 1892, when very erroneous and widespread conclusions were spread regarding the source of typhoid fever in Chicago, when it was assumed that the waters were all drawn from the long tunnels, it is now well known that a large part of the water on the north side was pumped from a so-called emergency tunnel extending out four or five feet in the lake, and ending with the breakwater. The engineers, anxious to make a record of economy in the use of coal, drew
4282 from the short tunnel, delivering a very contaminated supply, and the epidemiologist, seeing the results of this contamination, concluded that the supply, from several miles out, was badly polluted.

Q. Now, do you take into consideration, in passing judgment upon the water, its effect upon the people who use it?

A. I will have to answer that question this way: Inasmuch as it is practically impossible to determine the effect of the real Lake Michigan water on the people who are using it, or supposed to be using it, I am inclined to depend very little on the stated effect. So little dependence do I place on the statements of the epidemiologists and etiologists that I use and have used without boiling Lake Michigan water for twenty years.

4286 Q. Did you ever have typhoid fever?

A. No, sir, and don't expect to.

Q. Then you discredit the reliability of the effect of the water upon the people who use it as being no indication whatever of the sanitary condition of the water?

A. No, that is not what I said. I discredit the assumed effect of the Michigan lake water on the people of Chicago since it has

been determined that many of the conclusions have been drawn from not lake water, but from the sewer water pumped almost directly from the sewer. The most weighty and unsound conclusions
4287 that were drawn were drawn from water collected in that way.

Q. Now, then, state briefly, Professor, the source of pollution in water and the source of infection in water.

A. The addition to the water of trade wastes, household wastes, sewage and practically everything which does not belong in a normal water. The source of infection I can speak of only in a general way, as I am not an etiologist, a bacteriologist nor an epidemiologist. Infections are supposed by those who claim to have knowledge on that subject to come from so-called pathogenic bacteria, about which I am not testifying. * * *

Q. How do you differentiate between the two?

A. Well, as a chemist I would not speak at all of infection. I have been very careful not to go into a province which is outside of my line of inquiry. * * *

4288 This chemical knowledge, combined with the knowledge of the origin and source of the water in question, permits a comparison to be made between different waters as to the amount of their pollution. The work is of comparative value. I have not gone into the question of infection at all at any time.

Q. Then, as a chemist, any conclusions as to the sanitary conditions of the water from the chemical analyses that were introduced by the tables here would be unreliable, would it not, so far as infection is concerned?

A. That does not follow, because we must call upon our practical knowledge and practical experience regarding the source of water, as we know that infection in the general sense of the term cannot and does not take place in water except by the addi-
4289 tion of something else which the chemist can recognize and does recognize. These tables, then, have some value in measuring the relative danger or the relative safety of water.

4290 Significance of albuminoid ammonia.

4291 Significance of free ammonia.

Q. Now, there are certain diseases known as water-borne diseases, are there not?

A. I have heard of those.

Q. Do you recognize that to be a fact?

A. I am not discussing etiology.

Q. Well, what do you say on the subject?

A. Well, I say, as I said yesterday, that many of the conclusions of sanitarians on that point have been based on such
4292 faulty observations that it is quite unsafe to draw any general radical conclusions from them.

In answer to the question I will say that in forming my conclusions I have left out of consideration the question of infection, because it does not come within my province of discussion, but I cannot agree with the assumption of counsel in the question that that is the only point of importance to be considered here. I differ from that very decidedly and strongly.

Q. Is it the most important?

A. For the purpose of the examinations that I have made it is not the most important, at all. * * * The object of my investi-
gation has been to determine the extent and rate of destruc-
4293 tion of organic pollution in the water in question, and to compare these several waters with each other.

Q. Then it has not been with a view of determining whether or not the water is safe to drink?

A. In that narrow sense it has not been. I have declared that in my opinion none of these waters under consideration are safe to drink. * * * Well, I prefer Lake Michigan to the Illinois River as drinking waters.

Q. Well, is there any comparison to be made between the lake and the river?

A. Not as a drinking water, I think.

Q. What amount of polluting substances would be necessary to make the water of Lake Michigan unfit for drinking purposes?

A. I am not doing any guessing on the witness stand. I don't know.

Q. Did you ever find .1 of a part albuminoid ammonia (in Lake Michigan)?

A. I am not going to follow in tenths from one-tenth up to tenths to tell or attempt to tell where the line of demarkation would be between a bad water and a good water in Lake Michigan.

Q. Why do you decline to tell, **Professor?**

A. Because it has no bearing on my testimnoy in any way. It is simply a question which, if followed out consecutively, would lead to an impossible answer. I have been there before on such questions.

Q. That is one reason, is it?

4295 A. That is a good and sufficient reason for me at the present time. There may be others.

Q. Now, do your chemical methods enable you to differentiate between dead and living materials or dead and living organic matter in the water?

A. No, the chemical analyses certainly not, but the bacterial
4296 chemical tests which I have made indicate the presence of the living organic matter, as I have explained on several occasions.

Q. Professor, why do people boil their water which they think is unsafe for drinking purposes?

A. Well, I can answer that from the general standpoint. They have been told that there are germs in it, and they boil it. Some of them do and some of them do not. I don't know. Scientists, in recommending that, figure that by boiling it they will destroy this assumed infection.

Q. Now, you say assumed infection. Do you mean infection assumed upon your part or upon their part?

Q. Assumed upon the part of the so-called epidemiologist and others.

Q. As a chemist you know nothing about it?

A. As a chemist I know nothing about infection.

Q. So that when you testify or express an opinion upon the sanitary condition of water, aside from what your chemistry tells you, it is nothing more than the opinion of an ordinary citizen or layman?

A. Well, I think that is going a little too far. I believe the chemist, by his chemical methods, is still able to tell a great deal about water. I am very careful not to express an opinion,
4297 however, which is unwarranted by the extent of my investigations. * * * In expressing my opinion I made practically no use of the assumed experience of epidemiologists.

Q. You have never investigated the relation of health and water here at Chicago or anywhere else, have you, Professor?

A. Not in a very extended way, but far enough to show that the assumptions made by certain epidemiologists who claim that they have made studies of the water-supply of Chicago at several periods in the history of Chicago are not founded on sufficient knowledge of the facts to merit the attention which the publications really attracted.

Q. Now, Professor, will you state the reason why you have thus concluded?

A. I stated yesterday in some detail one of the main reasons for my lack of faith in the opinions advanced by these infant industry scientists called epidemiologists. It is well known that in drawing

their conclusions these people have been so often ignorant of the most important fact in the case that the conclusions are finally of no value. From my own studies and investigations, and from my knowledge of things as a citizen of Chicago,—facts which I have paid close attention to for over twenty years, I am able to state positively
4298 that in several of the most noted of these cases, where epidemiologists from abroad have passed on the condition of affairs in Chicago, they were certainly mistaken in their conclusions.

Q. Now, Professor, I would like you to state some of the conclusions that were reached by epidemiologists with reference to the water-supply of Chicago, and the reasons which you give, a substantial reason, a substantial fact, which makes you disbelieve the correctness of their position?

A. In answer to that question, I am willing to repeat in substance the statements which I made yesterday, which I thought was sufficiently definite. In two periods of the recent history of Chicago it has been assumed by epidemiologists that infection comes from certain of the tunnel waters brought into the city. It has been shown by investigation, which will be detailed here later, at the proper time, that before the World's Fair, at a time when a great deal was said about the infection of Lake Michigan water, a good part of the supply in one section of the city was drawn, not as was supposed, from the Chicago avenue tunnel, extending out about two miles, but from a short or emergency inlet, a short tunnel extending out to a distance of about 500 feet, to be used in case of emergencies, in case of a large fire, for example. * * * It was drawn from a point where there was considerable contamination in dumpings and washings, and sewers and so on. Therefore I say that the conclusion that the water from the two-mile tunnel was the source of the disease which the epidemiologists described at that period is not a fair conclusion. At a later period last year, through the spring and summer, last year, there was a remarkable epidemic of typhoid fever in Chicago. It was a very singular fact that the greatest prevalence of this appeared to be in a part of the city which received what was supposedly the purest water drawn from the longer tunnel, and a great deal was written and expressed in public addresses in regard to the infection of the water at that great distance, shown from the appearance of the fever in this part of the city. It was later discovered that through some accident or oversight which occurred many years ago, perhaps over ten or fourteen years, a connection was left between a well in the pumping station and a sewer, so that at the time of high water, at the time of heavy rains, it was possible for one of the large

sewers in that part of the city to flush over, and throw a great volume of foul water through a ten-inch pipe into this well, so that it could be drawn into the water-supply. That fact is known to many people in the city and in the engineers' office. I state that here, then, as a further explanation why I am not willing to accept the deter-
4299–4300 mination of the etiologist and epidemiologist. It is evident that that was not the source of the pollution in the mains in that part of the city.

From the tables which I have presented, and from the curves which I drew illustrating some of these tables, I made the statement that I believed the pollution from Chicago is the least im-
4327 portant, and a comparatively unimportant factor, in any residual pollution left at the mouth of the Illinois River.

Q. I will ask you if there is not more known harmless organic matter in the Missouri than there is the Illinois River?

A. No, I would say decidely not. We have no proof that the products of organic decomposition left in the Missouri River are any less harmful than the decomposition left in the Illinois River.

Q. Now, then, professor, in considering that proposition and in making the statement that you have just made, have you taken into consideration the character of the soil through which the rivers run and the population residing on these rivers and their tributaries?

A. I have, most decidedly.

Q. And have you taken into consideration the volume of the stream flow?

A. Certainly, certainly.

Q. Then one batch of organic matter is just as good as another, is it not?

4328 A. That doesn't follow from anything I have said at all. I should say no. Some organic matter is much worse than others.

Q. Then how can you tell about the absence of any sewage matter at Chicago at the mouth of the Illinois River?

A. In regard to the question of the presence or absence of sewage matter at the mouth of the Illinois River, I have reached my conclusions by observing the very rapid rate of change of
4332 organic matter as we go down the river, reaching finally a condition where the organic matter, as measured by the tests, is not at all larger than would be properly accounted for by what is going in from the tributaries and from the great contamination at Peoria.

Q. Then, Professor, from your last answer I take it that no correct analysis could be made upon which a creditable opinion could

be based, unless the analyses be taken from one end of the year to another.

A. No, that doesn't follow. A creditable opinion is an opinion that can be believed, and I insist that the opinion that I have given can be believed as much for these analyses as for any other.

Q. So that the opinion that you have given from the analyses that you have made represents correctly the conditions of the river at Grafton at all times of the year?

A. I believe the analyses which I have presented do represent those conditions.

Q. Now, Professor, assume that for the last ten years there shall be the same ratio of increase of free ammonia at Grafton as there is discussed in the samples analyzed by you for the years 1900, 1901 and 1902, what would you say as to the character of that water?

A. If for some reason not suggested by the question there should be a corresponding increase of free ammonia, I should think something had struck the mouth of the river.

Q. Well, with the water flowing down the river, would you say the mouth of the river was struck from the direction of its source or from the direction opposite its mouth?

A. Well, with the water flowing down the river I should say simply that some one must have dropped some dead hogs into the river to produce such results.

Q. Assuming that no such temporary and continuous action
4343 of that character were brought out?

A. Then it would be impossible to answer the question, as such an increase as was assumed has never been observed during a period of ten years, and could not take place.

4346 Effect of flood.

The total weight of the pollution in any large volume of water is the least important factor to be considered. If we consider the whole weight of common salt, for example, in Lake Michigan, you would have enough to poison an army, but in drinking Lake Michigan water we are not concerned with the total amount of salt present, but only the small amount of it which is contained in the water we work with; so in the Illinois River, we do not care, nor should anybody care, what the total amount of pollution is. We are practically
4349 concerned there and in other cases only with that part which is contained in a given volume. * * *

In answer to that question, I would say, as determined by my investigations, that the condition of the Illinois River at its mouth

after the opening of the canal is very much better than it was before the opening of the canal. It is evident from this fact that the conditions for the destruction, elimination and reduction of organic matter must, therefore, be better now than they were in 1899.

4351 Dilution does not necessarily destroy, but it renders less probable an effect in proportion to the extent of the dilution. The
4353 effect diminishes as the dilution increases.

I have not compared the gross pollution of the Missouri with the Mississippi or the Grafton pollution of the Illinois with the Mississippi. I say that for all practical purposes, for the purposes
4354 of household uses, such a comparison is valueless and absurd.

Q. Why is it that you said that no sanitarian can give a correct opinion or pass competent judgment upon the sanitary condition of water from the chemical analyses alone?

A. I think if I put the statement in that way that I must have been dreaming. I don't believe I made any such a broad statement to cover all possible cases, because there are a great many cases in which the chemist, from his chemical examination alone, can say that a water is absolutely unfit for use. He doesn't care where it has been or where it comes from, but in other cases where the evidence is not so pronounced or tangible, before coming to a conclusion it is a very good thing to know all the circumstances surrounding the his-
4357 tory of the water; and that is the careful analyst who, before venturing an opinion in a case which on its face is not plain, looks into these matters.

Q. I want you to state, professor, whether or not, if you know, that such living germs or living substances, disease producing, do pass from Chicago to the intake at St. Louis; yes or no?

A. Inasmuch as, in spite of all the investigations which have been made, no one has yet found a disease germ passing from
4364 Chicago to St. Louis, I am inclined to say that I do not believe that it could pass. No, I don't believe that a disease germ would pass.

Q. Then, professor, you do not know that these disease producing materials or substances of a living character do not pass from Chicago to the intake at St. Louis?

A. As a chemist, pure and simple, I do not.

Q. And further than that you decline to state?

A. Well, now, that is not a correct proposition.

Q. Well, do you state as a bacteriologist?

A. I do not speak as a bacteriologist, but I am very far from declining to speak on anything I know about.

Q. Do you know about this, about their passing from Chicago to St. Louis?

4365 A. I do not. I am not aware that any one has ever discovered their passage.

Q. Then, professor, why do you state that because in your opinion no typhoid germs have been discovered in the great number of samples that you have taken, that no such germs exist in the water of the river, you not being an epidemiologist, etiologist or bacteriologist?

A. My statement of opinion was based on the experiments of others, and again from the standpoint of an intelligent layman and not a bacteriologist. That was merely a question of probabil-

4368 ity. After these thousands of examinations have been made and none found there was no evidence apparently that they were there. * * *

It is my individual opinion as a layman that because out of these thousands of investigations no disease germs have been found, it strikes me as highly improbable that there is any reason for assuming that they are there. * * * As a layman it would not necessarily follow. From the standpoint of a layman it would not necessarily or absolutely follow, but the layman would naturally desire some

4369 stronger proof than has yet been presented, proof that a layman can appreciate and understand, if he is a man of fair

4375–76 intelligence.

Manner of selecting point where samples were taken at Wesley City.

4383 The chemical constituents of Peoria sewage from the distilleries and cattle sheds compared.

Q. Now, professor, I will ask you if there is anything harmful to your knowledge in the mash that is used by the distilleries after the spirits are taken from it?

A. In the fresh mash there is certainly nothing harmful, but I know of no fouler contamination or worse smelling or worse

4384 acting putrefying substance than this slop material when it begins to undergo bacterial decomposition.

Effect on the health of the people.

Q. The question is not, do you condemn the water of the Illinois River, but whether or not any of this pollution, polluted matter which was objectionable to you under the assumption with reference to the primal condition of the Illinois River filth, except as to the sewage discharge of the City of Chicago through the canal, which

existed at Grafton, whether it would reach the St. Louis water-works at the intake of the chain of rocks, a distance of thirty-four miles?

A. I have nowhere stated that. There was no evidence to show that any of this original pollution ever reached Grafton, and there would be still less evidence to show that it reached the chain of rocks.

If I have conveyed that impression in my answer, and I don't
4393 see how I have, it is a mistake. I insist emphatically that there is nothing to show that original contamination from the City of Chicago does reach the mouth of the Illinois River or the chain of rocks.

4395 RE-DIRECT EXAMINATION.

Location of the point at Wesley.

F. ROBERT ZEIT,

Direct Examination by Judge Springer.

4396 Professor in the Northwestern University Medical School. Was instructor under Professor Klebs for three years.

I made bacteriological examinations of the waters of the Chicago Drainage Canal in the Illinois River between February
4398 6th and October 1st, 1900. The samples were secured from Professor Long.

The specimens of water which I received from Professor Long were plated out on gelatin and agar. From three to sixteen dilutions were made in petrite dishes. * * * The object of our examination was partly to determine the presence of pathogenic bacteria or the absence of pathogenic bacteria in the specimens of water submitted. That was our function in the investigation. No other. We did not make any counts of colonies nor tests for fermentation or indol production, or any of the usual tests. * * * The plates were examined daily and pure cultures obtained on agar from the various
4402 colonies between the second and eleventh day. * * *

We further made a number of animal experiments with all the samples obtained or which were given to us by Professor Long. The experiments included intra-peritoneal injections of guinea pigs with four cubic centimeters of water of every station. Another set of experiments with the same waters included inoculation, also intra-peritoneally, with culture made by adding one cubic centimeter of suspended water to five cubic centimeters of nutrient bouillon and keeping the mixture in the incubator at a temperature of thirty-seven

degrees centigrade for twenty-four hours. Of these cultures, one cubic centimeter was injected intra-peritoneally into guinea pigs. The object of the latter experiments was to favor the growth of pathogenic bacteria and keep back the growth of non-pathogenic saprophytes and water bacteria. In other words, to enrich the water in disease-producing bacteria by adding a favorable culture medium and exposing them to a favorable temperature. Disease-producing bacteria are favored and multiply rapidly at thirty-seven degrees centigrade, whereas water bacteria would be somewhat held back by such a temperature. The culture thus enriched in pathogenic bacteria was injected intra-peritoneally and when the animal died cultures were taken from the blood, the heart blood, the spleen and lymph glands.

4403 Also smears were made at this time and a diagnosis as to the disease and the organisms causing the death was attempted and made in most of the cases.

STATIONS WHERE WATER WAS EXAMINED.

Lake Michigan, Seven Specimens.

Guinea pigs infected with four cubic centimeters of the different specimens of water, all recovered. Three of the specimens containing pathogenic bacteria were placed in the incubator. * * * Three

4404 guinea pigs were injected, only one died of sepsis. The blood of the animal contained coli bacilli. Subcutaneous injections caused only a local abscess. The animal recovered.

Western Avenue in the New Drainage Canal.

Thirteen specimens were examined. Four different kinds of pathogenic bacteria were found.

Intra-peritoneal injections of guinea pigs with four cubic centimeters of the sample of water did not prove fatal. Twenty-four hour mixtures grown at thirty-seven degrees centigrade with one part of water and five parts of nutrient bouillon caused a fatal septicemia by intra-peritoneal injection of one cubic centimeter. Several of the pure cultures of the bacilli coli communis obtained from these samples were non-virulent, whereas the above mixture invariably proved fatal.

Bridgeport.

Seven samples of water were analyzed. Pathogenic bacteria of five varieties found. The intra-peritoneal injections of four cubic centimeters of several samples of water into a guinea pig did not produce death, whereas one cubic centimeter of a mixture of one part of water to five parts of bouillon kept in the incubator over night at thirty-seven degrees centigrade proved invariably fatal to guinea pigs

at a short time. Even subcutaneous injections of one guinea
4407 pig produced a fatal septicemia.

Lockport.

Seven samples were analyzed; pathogenic bacteria of five varieties were found. Intra-peritoneal injections of four cubic centimeters into guinea pigs produced no effect.

Culture of bacteria was uncertain in its effect. Some animals recovered after two cubic centimeters of intra-peritoneal injections. One promptly died of sepsis. All those recovering had an elevated temperature and lost rapidly in weight for several days. One died two weeks later, after having apparently recovered. No cause for death could be made out on post-mortem, and no bacteria were
4408 found in the blood or the organs, nor in the abdominal cavity. In the animals which died promptly the proteus forms were most prominent.

Joliet.

Six samples were examined and three varieties of pathogenic germs found. Intra-peritoneal injections of four cubic centimeters into guinea pigs produced no effect. Of four guinea pigs inoc-
4409 ulated of one part of different waters and five parts of the bouillon, one died of sepsis, the others recovered.

Wilmington, on the Kankakee River.

Two samples were examined; no pathogenic bacteria found. Intra-peritoneal injections of guinea pigs of four cubic centimeters of water, as well as both the bouillon cultures, proved non-pathogenic.

Morris, Illinois.

Ten specimens of water were examined and four varieties of pathogenic bacteria were found. Direct intra-peritoneal injection of one specimen of this water caused the death of a guinea pig in eleven days. Other samples of water from the same place did not cause
4411 death by direct injection. Experiments with mixed cultures gave uncertain results, the animals sometimes dying and sometimes not.

Ottawa.

Five specimens were examined; pathogenic bacteria found with two. Both the water and the mixed cultures proved non-virulent after intra-peritoneal injections into guinea pigs in the same manner.

Fox River at Ottawa.

Four samples were examined and the coli was found. Neither the water nor the mixed cultures proved pathogenic to animals.

LaSalle.

Six samples were received; pathogenic bacteria found, three kinds. One guinea pig which received an intra-peritoneal injection of four cubic centimeters of this water died of sepsis. The others
4413 recovered, but the one to five bouillon mixture grown in the incubator for twenty-four hours proved very virulent to the guinea pigs.

Henry.

Five samples were analyzed and four kinds of pathogenic bac-
4413 teria were found. Direct injection of the water did not cause death. Mixed bouillon cultures were virulent.

Upper Peoria.

Five samples were analyzed. Coli bacilli found. * * *

Direct intra-peritoneal injection of water as well as mixed twenty-four hour bouillon cultures proved entirely non-virulent. Even large doses of a twenty-four hour culture at thirty-seven degrees centigrade of one part of water and five parts of bouillon could be given to guinea pigs by intra-peritoneal injection without causing death.

Q. State what evidences of bacteriological purification are
4414 indicated by these examinations at this place, and the preceding examinations about which you have testified.

A. I found that there was a gradual decrease in the number as well as in the kind of pathogenic or disease-producing germs in the water specimens submitted as we got further away from Chicago. Further, I have found that bacteria that are generally known as sewage bacteria or saprophytic organisms gradually decrease as we approach Peoria. The number as well as the kind of disease-producing bacteria, as well as the sewage bacteria, is continually decreasing to this point, and the absence of pathogenic effect in animals, I
4416 think, is also a sufficient proof that the zone of bacteriological self-purification which every river has which has been polluted, must be located somewhere above or near upper Peoria.

Lower Peoria.

Eleven samples of water analyzed. Three kinds of pathogenic bacteria found. Direct injection of four cubic centimeters of samples caused the death of the guinea pig in seven days. An-
4418 other animal died of sepsis within twenty-four hours after inoculation. The pathogenic bacteria and saprophytic bacteria have again markedly increased.

Havana.

Twelve samples of water were analyzed. Six kinds of pathogenic bacteria were found.

Several of the specimens of this water proved pathogenic to guinea pigs and white mice when intra-peritoneal injections were given, and numerous animal experiments were necessary to prove beyond any doubt that anthrax spores must have been in two samples of this water. We injected finally pure cultures of all anthrax-like organisms obtained from these specimens. A number of the animals died within forty to forty-eight hours of anthrax bacteriemia. The blood of all the organs contained enormous numbers of anthrax
4419 bacilli. The colon bacilli and the staphylococcus aureus found a few times in these samples proved non-virulent when pure cultures were injected into animals, whereas the proteus forms were very virulent.

Spoon River Near Havana.

Eight samples were examined and pathogenic organisms were found in three varieties. Intra-peritoneal injections of four cubic centimeters of water in guinea pigs in two cases did not prove fatal. Cultures of this water, one part, bouillon five parts, kept at thirty seven degrees centigrade, were non-virulent in doses of one cubic centimeter by intra-peritoneal injections.

Pearl.

Ten samples were analyzed; pathogenic germs of two varieties were found; neither water nor culture one to five was pathogenic by intra-peritoneal injection.

Grafton.

Ten specimens of water were examined and three varieties of pathogenic germs were found. Intra-peritoneal injection of four cubic centimeters into guinea pigs did not prove fatal. Mixed
4421 cultures, one to five, were non-virulent.

Comparison of Saprophytes with Pathogenic Bacteria in Water.
4424 Experiments on the Life of the Typhoid Bacillus.

Effect of Pathogenic Bacteria by the use of the bouillon culture at a certain temperature and the assistance which that
4428 method gives to bacteriologists.

Q. What is the accepted opinion of pathologists as to the probable effect of taking into the human system one bacterium of typhoid or a single organism of any pathogenic kind?

A. It is true that in all diseases, all infectious diseases, the number of the germs is very, very essential in producing an infection.

We may have a germ and it may be virulent, and even the resistent force of the organism may be decreased, and yet we may have no effect, no infection, even in cases where there is a certain known source of infection to which many people have been exposed. The same holds true, not only of typhoid bacilli, but of all other germs. * * * The number of typhoid bacilli essential to produce infection are not found in the amount of water usually used by an individual for drinking purposes, but the lake or river water. I do not
4430 believe personally that a direct infection can take place in such a manner. * * *

Q. Assuming the conditions that ordinarily prevail in the Chicago Drainage Canal, and the Illinois River, what would you say as to the relative longevity of the bacteria found therein?

A. I would like to separate those two a little, that is, the Drainage Canal proper and the Illinois River. I think that in the Drainage Canal the growth and multiplication of immense numbers of saprophytes due to the presence of a large quantity of organic material, is unfavorable to the life, the multiplication, or even the existence of disease-producing bacteria. I believe that in the Drainage Canal the conditions must be such that they are gradually wiped out, whereas in the Illinois River the saprophytes are less numerous and any disease-producing bacteria that would enter the Illinois River would be tremendously diluted, but they could probably exist longer in the Illinois River than they could in the Drainage Canal. Any disease-producing bacteria that would get into the Illinois River could, on account of the absence or the decrease in the number of saprophytic bacteria, live longer. The question could be answered by saying that in the Drainage Canal the existence or multiplication of pathogenic disease-producing bacteria would be made impossible, and that they would disappear in such a sewage tank during the overgrowth of saprophytes. The time, of course, would depend, also, upon the resistance of the organisms, but, under the conditions of my labor-
4433 atory experiment, I would judge that a week ought to be sufficient to wipe out all the cholera vibrio staphylococci and typhoid bacilli.

Manner of receiving samples from Professor Long for the period between October 3, 1901, and March 11, 1902.

4435 Examination of the Illinois River at Grafton, Mississippi River above Grafton and Missouri River immediately above its mouth.

4438 Thirty-six samples were examined from the Missouri River.

4442 Table of thirty-eight water specimens from the Illinois River.

4446 Thirty-seven water specimens from the Mississippi River and table of analyses.

4447 Thirty-six water specimens from Missouri River and table of analyses.

Q. In your testimony toiday- in reference to your examination of waters of the Illinois, you stated that the bacteriological self-purification of the Illinois River began at Morris and was practically complete between Henry and upper Peoria.

A. Yes, sir.

Q. Now, state whether the results of the examination to which you have just testified strengthen or weaken those conclusions in regard to the water at Grafton?

A. Bacteriologically, I do not see any reason for changing the opinion expressed. That bacteriological self-purification has taken place in the Illinois River long before the water reaches Graf-

4449 ton.

Q. What efforts did you make in these examinations for the purpose of the identification of pathogenic bacteria and for the purpose of determining the virulence of such bacteria?

A. I have platted out the suspected water and obtained pure cultures of the various organisms found, passed them through the usual cultures in order to identify them, and immediately after plating out I have added to the suspected water enough bouillon, nutritive bouillon, to the four-ounce bottle of the specimen of water, to favor the growth of the bacteria therein, and incubated the whole bottle for twenty-four hours at twenty-seven degrees centigrade. After this time I injected one cubic centimeter of this water, enriched in pathogenic or disease-producing bacteria, intra-peritoneally into guinea pigs. When the animal died a complete bacteriological examination was held and the cause of death determined. Cultures were

4450 made from all the organisms of the animal, particularly the blood, the spleen, and the lymph glands, and the contents of the abdominal cavity.

The colon bacilli were found in the Illinois River thirteen

4452 times, in the Mississippi nineteen times and in the Missouri twenty-six times.

Q. Knowing, as you do, the conditions that exist on the watershed * * * between Chicago and St. Louis, is it possible, in your opinion, for typhoid bacilli deposited into a sewer in Chicago which empties into the Chicago River to survive the passage and enter the intake of the St. Louis water-works?

A. In my opinion, it is not possible that they can reach there.

I have said before that my opinion is based upon the fact that whenever conditions are made favorable for the rapid multiplication of saprophytic bacteria, pathogenic bacteria disappear, and it is my opinion, further, that the reason why reputable bacteriologists have been unable to find the typhoid bacillus in the polluted supply of
4458 streams, or localities where a typhoid epidemic exists, was due to the same cause.

In regard to the bacteriological flora of the three rivers, at that time, from the investigations made as a bacteriologist, I would judge that the Missouri was more polluted than either the Mississippi
4459 or the Illinois during the period of these examinations, and that the Mississippi was more polluted than the Illinois at the same time.

This investigation is entirely independent of any other data. It is simply to determine if the water of these three rivers, specimens of which were examined, is to all condemned bacteriologically, and which of the three is more dangerous than the other two, and I think bacterially and quantitatively that can be determined a great deal better in this way than by a great many of the methods that are employed sometimes as the more dependable methods by sanitarians.
* * *

I would be perfectly willing to swallow water in which I was capable of producing culture like I have done here, and keep it twenty-four hours in the incubator, and inject it intra-peritoneally into the abdominal cavity of the guinea pig without any effect. After all, the question of determining the safety of drinking water from a river or lake does not depend upon its physical character and the number of bacteria that may be present, but depends upon the
4460 number and kind of pathogenic bacteria present in the water.

I testified as a medical bacteriologist and I believe my opinion in this matter has some cause and some justice.

Difference Between Bacteriology and Sanitation.

I believe modern sanitation owes its advance mainly to the advance of bacteriology. Modern epidemiology and sanitary science has been entirely changed, as we have learned to know the etiology of infectious diseases and their spread, so the modern sanitation makes a specialty af applying that which we have learned from chemistry and bacteriology and associated branches in the study of infectious
4462 diseases, as well as their prevention, et seq.

Method of ascertaining the presence of the prodigiosus in
4464 water.

Q. What do you say as to the significance of the red color to which you have referred?

A. The significance of the red color is not so great that by it
4464 alone we can distinguish a prodigiosus colony.

Q. Have you discovered the presence of any bacilli which disclose the red color to which you have referred?

A. I did in Lake Michigan.

Q. Please state the facts.

4465 (Facts follow.)

The zone of bacteriological purification is that part of a sewage-polluted river where saprophytic organisms and pathogenic bacteria have disappeared and where the normal bacterial flora of the river before it received such pollution is again established.

Examples where the zone of bacterial purification of rivers has
4466-4467 been established. The same in Paris. The odor at Breslau. The Limmat in Switzerland. The Isar in Munich.

Q. Returning, then, to your conclusion in reference to the zone of bacterial purification having been reached at Peoria, state whether the conditions which you took into consideration and upon which you reached this conclusion are materially different from those existing elsewhere, where a similar conclusion has been reached as to other rivers?

A. I think the zone of purification here ought to be even nearer to the City of Chicago than what I have allowed. In fact, I think that the zone of purification is above upper Peoria. I spoke
4469 of it there as being simply bacteriologically complete. I believe that the real zone of bacteriological purification is complete very soon after leaving the Drainage Canal.

DIRECT EXAMINATION,

By Mr. Todd.

Q. Professor, as an expert bacteriologist and pathologist, what is your experience as to whether a typhoid bacillus lying in the bed of a stream for a period of sixty days would be able to cause typhoid fever, taken into the human system after it had remained in such sediment for such time?

A. My opinion would be that it is dead by that time under
4471 these conditions.

Question as to whether sewage from Chicago would be a danger and a menace to the citizens of Missouri. This answer:

A. As to the pathogenic bacteria, it is my opinion that there
4472 would be no source of danger to St. Louis or to the inhabitants of Missouri using this water for drinking purposes.

From my examination I conclude that bacteriologically the Illinois River was less polluted than either the Mississippi or Missouri.

The effect of mixing the Illinois with the Mississippi and Missouri is answered as follows:

A. I can only judge from the result of these tables, and if such a condition would exist and would have existed during this time, it would have only tended to make the Missouri less infectious to add the water of the Illinois to it, because the Illinois River was less infected than either the Mississippi or the Missouri. So, during those times I would say that there would have been no source of
4474 danger to add the Illinois to the already severely polluted Mississippi or Missouri.

I do not believe that the Drainage Canal or the sewage entering the Drainage Canal can be of any danger due to pathogenic bacteria remaining in it to St. Louis or Missouri, for the reasons already stated, my opinion being based mainly on the behavior of pathogenic bacteria in the presence of saprophytes, and my opinion being based on the general knowledge, the world over, of the existence of a
4474 bacteriological zone of purification in any river, and a continuous and permanent purification as the river flows along.

I am thoroughly convinced that typhoid bacilli, even under the the most favorable conditions would not live one year, much
4476 less five years.

I don't think that it is possible for typhoid fever bacilli to be
4476 deposited on the bottom of the Illinois River, for the same reason that I feel certain that the typhoid bacilli would not live one year.

Prodigiosus Hypothetical Question.

4476 CROSS-EXAMINATION,

By Mr. Jeffries.

Q. Professor, what experiments have you made with reference to the life of the typhoid germ?

A. I have inoculated liter flasks with known quantities of
4482 the typhoid bacillus in lake water in the Missouri River water, in the Mississippi water and into the Illinois River water.

4483 Methods Employed in the Experiment.

Under all conditions we were unable to find colonies of typhoid bacilli in this river water after six days, even in those experiments

where we had inoculated large quantities of bouillon culture
4486 into it. All these experiments were done in a refrigerator.

I believe that the conditions in a seriously sewage-polluted water are more unfavorable for the life of a typhoid bacillus than they would be in the laboratory experiments, on account of
4492 the greater amount of organic material that would be present there.

The real cause of any difference between laboratory experiments and natural conditions exist, however, in the fact that the excretions of saprophytes as they multiply in the test tube are not carried away as rapidly in the running water or the river water as they
4493 would be in the test tube. That is really the only point where the tube could be called not identical.

I speak of the general proposition that any river ought to be polluted as little as possible where it is necessary that towns
4495 near by use that water for drinking purposes.

Relation of Bacteriology to Hygiene.

4496 Zone of Purification by English Authorities.

Q. Then you reason, professor, that because the non-pathogenic bacteria have disappeared in those rivers, that the pathogenic bacteria have disappeared, also?

A. Yes, sir; for the reason which I stated several times, that saprophytic bacteria decrease much more rapidly, or as they increase more rapidly pathogenic bacteria disappear, and that if sapro-
4497 phytic bacteria have decreased in number the pathogenic bacteria must have been disappearing long before the saprophytes did.

In passing a general opinion as to the potability and safety of water for drinking purposes, temperature of the water, stream flow, stages of the river, should all be included, as well as the chemical and bacteriological examinations, in order to arrive at the potability of the water. I only express an opinion in regard to the bacterio-
4505 logical purification at that place (Peoria) in the absence of pathogenic bacteria.

You do not determine the sanitary condition of any water purification by bacteria. You only determine the bacterial pollution of the river or lake water by bacteria, and not any other element. Bacteria has nothing to do with the final judgment. * * * A water may be bacterially pure and may be chemically impure, and vice versa. * * * The opinions I have expressed all the time are purely

on bacterial grounds, and every judgment I may have expressed in this matter is purely based on my experience as a bacteriologist, and also my experience with the water of this river, and only refers to the contents of the bacteria in the river, and not to the chemical
4506 or physical aspects of the question whether the water is potable or not.

I made the statement that when organic matter increases that the saprophytic bacteria multiply more rapidly and overgrow the pathogenic bacteria, and that they, therefore, die sooner in the
4508 presence of organic matter than the saprophytes, than they would if there were no saprophytes and large quantities of organic matter present.

My opinion is that a pathogenic germ will live longer in water that does not contain any other bacteria at all than in water that contains organic material and saprophytic bacteria. The greater
4511 the dilution the further apart will be the individual bacteria and the less effect the growth of the saprophytic bacteria exert upon pathogenic germs.

Pathology includes all the causes and manifestations of dis-
4520 ease, as well as their results, a study of tissue changes and disturbances of functions of various organs.

I have not in that connection studied the causation of diseases as much as I have in connection with bacteriology—infectious diseases you refer to. As far as infectious diseases are concerned, I have studied those more from the standpoint of a bacteriologist. * * * With regard to the causation of these diseases, the cause is the infecting organisms, and I have studied the infecting organism, the
4521 biology of the infecting organism, as well (as I stated before) as how it enters the human body a d the changes that it produces there.

I am unable to state with regard to these experiments whether in all cases the typhoid bacillus I used was a virulent bacillus or not, because I have not in all cases tested its virulence upon guinea pigs.

The problem was simply to find the typhoid bacillus in water
4524 which I had inoculated with it, to see whether it would remain alive in water. The problem was not as to whether it would lose or increase its virulence in that water.

Methods employed for keeping typhoid alive for any length
4524 of time.

The typhoid germ has the faculty of growing as a saprophyte,
4525 and if you wish to have it described so, we will call it a facultative saprophyte, and not a pure or obligate saprophyte. As applied to the system of man, it is a parasite, and at no other time.

We frequently find that a parasitic germ will grow much better after it has grown a few times as a faculative saprophyte. It
4526 may be more virulent when coming from the patient than it would be in our cultures, but it would grow better and be more hardy perhaps.

The typhoid bacillus can grow in the presence or absence of oxygen. It can grow without any oxygen. It is not an obligate aerobe.

The amount of oxygen on the surface of my bottle of water
4528 is the same as the amount of oxygen that exists in the air, and ought to be the same as that at the surface of the river water.

Q. Now, Professor, increased oxygen in the water has a tendency to kill off your saprophyic bacteria, has it not?

A. No, sir, that is not certain. The bacteria which are called obligate aerobic require oxygen for their growth. If you take
4530 the oxygen away they will not grow. Oxygen does not act as a germicide at all. An anaerobe may be a saprophyte or it may be a parasite. An anaerobe grows only in the absence of oxygen.

The colon bacillus is a facultative saprophyte.

Q. How is that?

A. It is a parasite, but has the faculty of existing as a saprophyte, so I call it a facultative saprophyte.

Q. Now, Professor, is there any sharp lines between saprophytes and parasites?

A. We find that some organisms appear to be purely saprophytic organisms, and do not grow at all on dead organic material, so that is an obligate parasite, whereas we find that a number of the disease-producing bacteria can be made to grow on dead organic material, so those can be accustomed to live as saprophytes, that is, on dead organic material.

Q. So you draw the line of demarkation between the two?

A. Yes, I think we ought to draw the line, and we ought to say that there are some bacteria that grow only on living organic material (obligate parasites), and then there are some that live only on dead organic material and are destroyed immediately they are injected into the tissue of man or animal (obligate saprophytes), and then there are some that stand between these extremes, favor-
4534 ing the living organic matter, but capable of existing on dead organic material, facultative saprophytes.

Injection of guinea pigs with typhoid germs, if you use enough of it under all conditions, providing the germ is alive and virulent, will cause death in a guinea pig. In the colon bacillus there is a

difference. I don't think the two can be compared. An injection of boullion culture of typhoid bacilli will produce no infection of the animal. The animal dies of the poison of the typhoid bacillus, so it is a toxic effect; the animals cannot get typhoid fever. In the colon bacillus that is quite different. If you can inject colon bacilli
4536-37 in large quantities you can also kill the animal by the poison of the colon bacilli, but usually a virulent colon bacillus will cause an infection, and the animal then lives for about five or ten days, then dies with septic peritonitus.

Waters which are teeming with saprophytes usually are found by the chemical test to be very bad. We must judge the potability of a water by three tests: first, the physical characteristics of the water may be bad. Now, if they are not bad, then the chemical characteristics of the water may be bad, and if both of these are good, then there still may be the third point, the bacteriological character of the water may be such as to condemn it, but the bac-
4538 teriological character may be good and the others bad; why, then, of course, I would condemn it on other grounds than purely bacteriological grounds.

I have never investigated any typhoid infected water where
4541 I have been able to discover the typhoid bacilli, except in laboratory experiments, when I infected a water with typhoid bacilli.

By the term "overgrowth of saprophytic bacteria" is meant that they would increase at the temperature of water much more rapidly than the pathogenic bacteria, which would not multiply at all at the temperature of water. While pathogenic germs need not be directly killed, they would certainly not multiply at the temperature of water, whereas the other saprophytes and water bacteria would multiply, and they would increase in the presence of organic matter at such a tremendous rate that they would overgrow the pathogenic bacteria. To illustrate, if we take grass seeds and we take the seed of one tropical and delicate plant which can only grow under a different climate and different temperature, and you sow all out together, the conditions of temperature will be favorable to the grass seeds, and they will be grown up rapidly and exterminate by their overgrowth the more delicate plant or flower. So it is with disease-producing bacteria; when they are mixed with saprophytes, or when they are mixed with water bacteria and exposed to a temperature unfavorable to the growth of disease-producing germs, but very favorable for the rapid multiplication of saprophytes, whose dense growth make life and existence impossible for the disease-producing germ, in my opinion that is the

most important cause of the disappearance of pathogenic bacteria, even in laboratory experiments. We see the same competition of micro-organisms in the laboratory daily when we sow out a mixture of three or four germs, and the conditions of temperature for one are more favorable than for the other. Some will be wiped out by others for which the temperature is more favorable. The same occurs in water into which equal quantities of germs have been inoculated. When this water is platted out some of them will grow so thickly as not to allow the others to appear at all, and yet we
4551 know that they have been alive and know they were there, and yet they cannot grow. They disappear.

If pathogenic bacteria are in the water and have not died there yet, they will be distributed and separated more or less by dilution, * * * which is probably the reason why we do not find them. * * * In order to produce an infection it would be necessary that they should first reach conditions favorable for multiplication. Take the case of the typhoid bacillus; one germ might be in a barrel of water, and if that one germ happened to get into a milk can during a hot summer day of twenty-four hours, perhaps this bacillus would find in the milk a favorable culture medium, and the persons drinking that milk would drink a culture of typhoid bacilli, whereas one would have to drink all that water to get one bacilli, and further, one germ alone would not produce an infection. Numbers are very essential to produce an infection. In order to produce typhoid fever the germs must be swallowed. It must be virulent; it must be swallowed in great enough numbers, and even then the resistent force of the organism must be decreased. We see occasionally where the infection has been traced to milk that some people partaking of
4552 it develop typhoid fever and others do not.

From my own investigation of the matter, I look upon the drainage canal as one big sewage tank, even as it is now with an increased amount of water, and I hardly believe that very much will get out of the drainage canal in the way of pathogenic bacteria
4567 alive, because the conditions are certainly such as to show no lack there of organic material and no lack of saprophytic life. Places where bacteriological purification has taken place and
4575 reference to the authorities supporting the contention.

The organic material which entered the river with rapid multiplication of the saprophytes accounts for the increase of bacteria, and as the organic material became less was consumed, was eaten up by the bacteria. The condition for life and multiplication of saprophytic bacteria became unfavorable, and they died out. * * *

This is a fact which holds true in all cases of rivers, that the rapid multiplication of saprophytes corresponds to the great quantity of organic matter present, and that if these great numbers of saprophytes disappear the organic matter has been consumed. * * *

That is not a theory; that is something that we can see in the
4581 laboratory right along. When the organic bacteria in the water has been consumed by the immense multiplication of bacteria the number of bacteria decreases from day to day.

4583 Cumberland epidemic discussed.*

Q. I will ask you if there is any other people on the face of the earth that have made more thorough investigation of this subject than the English people?

A. Yes, sir.

4591 Q. Who are they?

A. The Germans.

No city should use water from a river unless that river water
4592 be filtered.

The more sewage the more rapid the disposal of the disease
4596 producing bacteria on account of the overgrowth of saprophytes.

From my experience I would judge that typhoid bacilli could
4607 live in ice for thirty days.

As to the effect of ice carrying typhoid the following answer was given:

"In the first place, the typhoid bacilli arriving in the drainage canal would have to pass through the sewers of Chicago, and in the temperature there would have been such rapid multiplication of saprophytic bacteria, due to the great quantity of organic material, that in my opinion the typhoid bacillus never reaches the drainage canal, at least the lower part of the drainage canal, and probably not even the upper part of the drainage canal. In my opinion they are dead when they arrive in the canal, because the sewage in our sewage systems is in a much more favorable condition for the growth of saprophytes than the drainage canal. This depends, of
4609 course, upon the length of time the sewage remains in the sewers.

Just as soon as colon bacilli overgrow them they disappear. Competition between different bacteria is of such a nature that the overgrowth of one is the cause of the destruction of the other, though

*In arguing the Cumberland epidemic, review this testimony.

I am reasonably certain that when one kind has disappeared
4611 and another kind has increased at a tremendous rate that the cause of the disappearance or the destruction of the one was due to the overgrowth of the other.

Q. Is it not natural to assume, Professor, or to suppose, speaking now from a standpoint of analogy, as applied to the science of bacteriology, that if they live for five, six or seven days in the laboratory samples of the water taken from the canal, that they would live ten or twelve days in the canal proper?

A. That may be true, but the very opposite may be true. It might be similar to conditions existing in the river Ganges. Cholera vibrio lives longer in the laboratory experiments than they do in this river, so the very opposite may be true also. I have not admitted that this production of the saprophytes necessarily is harmful to the typhoid bacilli, and therefore destroy them sooner. It may be
4612 that the diffusion of these saprophytic products under normal conditions in the drainage canal causes a still earlier disappearance of typhoid bacilli.

I don't believe they would travel at all. I think they would
4614 be destroyed by the time they reach the bear-trap dam.

Tetanus spores are found in nearly all garden, earth and street
4622 dirt, and could therefore be washed into a river during any heavy precipitation. Anthrax spores are not commonly found free in nature. They must come from an infected animal or infected person.

Tetanus is not produced by swallowing the germs. Tetanus is produced by inoculation subcutaneously in the form of a wound, not by swallowing. In order to inoculate tetanus bacilli must en-
4626 ter the deeper parts of the skin where there is no air. Otherwise this germ cannot multiply. They will only grow in the absence of oxygen. * * *

I will repeat again, first, the germ must be present to produce infection; second, the germ must be in sufficient quantities to produce infection, and, third, the germ must be virulent. Fourth, the
4641 resident forces of the organism must be decreased. These are the four conditions in which infection takes place, so that the simple finding of the germ alone would not mean that infection would take place.

Q. Isn't it possible that any one of the germs, if given sufficient conditions in the human system, would produce disease?

A. According to my opinion, no.

Q. Not even if the person is out of order?

A. Not even then, for the reason that over 90 per cent. of the persons dying have healed tuberculous foci somewhere in their body, so that 90 per cent. out of every hundred of us are infected with tuberculosis bacilli, and yet we do not die of the disease.

1642 Q. Is it not a fact that they differ widely as to the number of deaths during which typhoid germs may live in water and in sewage?

A. I think that the majority of bacteriologists are pretty well agreed that typhoid bacilli can live but a short time in water as well as in sewage, and shorter in sewage, of course, than in water,

1651 and that the longer they live in water the purer the water and the more free the water is from saprophytic bacteria, and water bacteria, the longer they live.

In my experience with river water, the shortest time was five

1653 days, when I was unable to find them.

Q. So that with it all there is no way of telling just how long they will live outside of the laboratory?

A. I think there is a way of telling it outside of the laboratory, how long they will live in the river, but I don't know that that has ever been tried.

Q. Is it not also true that one observer found it alive after 392 days?

A. Oh, we have in medical literature all sorts of statements. You must not forget that bacteriology is a young science, only twenty-five or thirty years, and over-enthusiasm has done more harm to it—I, for one instance, remember with regard to the typhoid bacillus that one man found typhoid bacilli in the gall bladder fourteen and one-half years after the patient had had typhoid fever, and they were alive. Well, that is quoted also in the literature, and might be quoted by you.

Q. And it might be correct?

1656 A. Well, not according to what I know of the biology of the typhoid bacillus.

In regard to Asiatic cholera leaving Chicago and arriving in St. Louis, the witness answers as follows:

"If they were not killed before they would of course arrive there. I wish to add that even if they did arrive there, even if they should enter the chain of rocks intake, we would again have to consider the same conditions which I have mentioned so many times. That is, the germs would have to be swallowed in sufficient numbers, they must not have lost their virulence, and the resistant forces of the body must be reduced because Professor Pottenkofer swallowed fresh

boullion culture of the cholera vibrio,—the Asiatic cholera vibrio,—
repeatedly to bring the experimental proof that if the resident
4658 forces were normal you could not produce Asiatic cholera.
He overcame the infection of virulent cholera vibrio in great
quantities. He took the same food that he took all the time,
4660 etc.

Q. But, under your theory, Professor, assuming that typhoid fever is always present in the same quantity in the water that is being used, wouldn't it be natural to believe that there would be more typhoid fever in the summer than at any other time during the year?

A. I have also an explanation for that. The reason why there are less cases of typhoid fever in the summer than in the spring and fall is because in the summer the temperature of the water is more favorable to the life and growth of saprophytes, and if any typhoid bacilli do get into the water they are rapidly overgrown by saprophytes more rapidly than in the fall and winter, when the temperature is low. I realize that my theory is perhaps not quite accepted by some epidemiologist, but I have reasons for it which are entirely based upon the biology of the germ and its behavior when it gets
into competition with other bacteria, such as water bacteria
4663 and saprophytes, as observed in the laboratory experiments
stated.

Q. But, Professor, upon your theory of no direct infection of drinking water, are you not diametrically opposed by many of the leading pathologists, epidemiologists, bacteriologists and sanitarians?

A. I think I am not. I believe that most epidemiologists admit the great role of importance that this indirect infection plays in the
epidemics of typhoid fever from the history of Chicago epi-
4666 demics and the reason there for indirect infection.

Q. Now, Professor, how do you explain the fact that children appear to have taken the disease at school, workmen in factories, and persons in many places where there is no food?

A. They take their lunch, and they may take their milk along and the milk can may have been washed out with polluted water containing one typhoid bacillus. Again, the same proposition, they take it into a warm school room or factory room, and by the time it has staid there four or six hours they are drinking a culture of typhoid bacilli. * * *

You pre-suppose a number of conditions which I have convinced myself are impossible, so what is the value of an opinion on such a hypothesis.

Q. It may be of great value to me, and I admit that you do not accede to all these assumptions, but assuming or taking it for granted that all these assumptions are true, what would you say?

A. The most serious one of the assumptions in your question is that bacteriologists have found in river waters typhoid bacilli for thirty days. Now, that is not so.

4687 Q. Even if all these assumptions were true, the possibility o millions of typhoid bacilli coming from Chicago to the chain of rocks would be absolutely impossibe. Even if all the typhoid bacilli of the typhoid cases in Chicago would reach without destruction to the chain of rocks, the dilution would be such a

4690 tremendous one that but very few of them would enter the inlet.

A. I do not like to answer the questions which are put on such purely theoretical assumptions, and then afterwards be accused of having expressed opinions that are not in harmony with Mr. Jeffries' conviction. I do not wish to go on record as saying that if all the germs or bacteria of all the typhoid fever patients entering the river, if there was absolutely no destruction whatever by any saprophytic bacteria, or products could reach the chain of rocks, that none of those that should get there, get into the intake. I stated, and want to be understood that the dilution would be such a tremendous one that there would be very few only, and that those few would not produce infections by drinking that water containing them. This is the idea which I have expressed right along of not believing in direct infections of water that contained greatly diluted typhoid discharges, so if you say that I have denied the possibility of any typhoid

4964 bacilli entering the inlet under the assumption stated, I have either expressed myself wrongly or you have misunderstood me.

Q. I want to ask you, that if you shoud deposit three or four virulent typhoid germs into a cubic foot of water, knowing that these germs were in that water, would you recommend that water

4696 for domestic use in the household?

A. I would not.

Q. Wouldn't there be great danger of producing this growth upon vegetables and various media in the house or in the room where the family live, if the water was taken into that room containing these germs?

A. If the water contained living typhoid bacilli, yes.

Q. Now, that I understand is your theory of the matter. In other words, that the infection comes on account of the growth of the germ upon some media of the room rather than upon taking the typhoid directly into the human system by drinking the water?

A. Now, Mr. Jeffries, you have continually called that a theory of mine. It is not. This is the accepted opinion of the ma-
4697 jority of sanitarians the world over.

Q. What is it that destroys the typhoid germs? In other words, is it an absolute warfare between the saprophytes and the parasites, or is it simply because of the overgrowth of one that the other disappears?

A. The factors are the following: First, the overgrowth of saprophytes; second, the excreted material present in the water of these saprophytes. The more organic material present the more rapidly do these saprophytes multiply, and the more of these excretion products. Third, the temperature; the more favorable the temperature for the growth of saprophytic life the more rapid the destruction of the typhoid bacillus. I might now add another factor which
4701 I have never mentioned, and that is the factor of sunlight, the destructive effect of sunlight upon all disease-producing bacteria in river and in lake. * * * In my experiments I excluded the effect of sunlight entirely.

RE-DIRECT EXAMINATION.

4711 Quotation of authorities, such as Franklin, etc.

4714 Indirect infection, according to Rubner.

4717 Typhoid bacilli, according to Hill of Boston, and Winslow, under Professor Sedgwick.

4721 Anthrax infection of a river in Wisconsin.

4736 Medford anthrax epidemic where a human being died.

4731 Professor Rubner. Bacterial qualifications.

I think by his studies in the bacterial laboratory he would be
4740 entitled to be considered an authority with regard to the life of this bacteria on which he has expressed an opinion.

4744 Adolph Gehrmann:

Am a physician and bacteriologist, and am connected with the Chicago Department of Health in the capacity of bacteriologist

4746 Method of receiving samples at the Chicago laboratory.

Arrangement made between Professors Palmer Burrill and
4749 Jordan for the selection of samples.

4752 Directions given to sample takers.

4754 Places where water was collected from Chicago to St. Louis.

4756 Names of water collectors.

4764–69 inc. Jeffries' objection to the introduction of tables of analyses.

4770–4807 inc. Table of analyses.

Q. Then, if we assumed that there is such a thing in the Illinois River as a zone of bacterial purification, where, in your opinion as a bacteriologist, is this zone to be found in the Illinois River?

A. There is a point above Averyville where the conditions of the number of bacteria exist about equal to that of the tributaries of the river, and the water here shows the least number of bacteria in the course of the river to the point at which they increase
4814–15 next below. I should therefore say that a degree of purification had taken place at about the location of Averyville in the river.

I should conclude from this that the waters of the Illinois
4818 River at Grafton show a much greater bacterial purification than those at Wesley City and at Peoria.

4820 Discovery of the bacillus prodigiosus.

4823 Methods of applying antiseptic precautions to the excreta of typhoid patients in Chicago.

4861 Prodigiosus in the United States.

4767–68 The causes of the local epidemic in the nineteenth ward in 1902.

Q. But the best test, Professor, of the sanitary condition of water is the effect that it has upon the people using it, is it not?

4872 A. Yes, that is a better index than the simple finding of colon bacilli.

Q. Are you of the opinion that disease-producing micro-organisms will live longer in highly contaminated water than in water that is not contaminated?

A. No, I believe that in highy contaminated water, where decomposition and the action of saprophytes is very active, the
4873 pathogenic organisms or disease-producing organisms are more quickly destroyed.

The difference between one typhoid infected germ and a num-
4873–74 ber of typhoid germs and its effect in water.

COUNT MAX LE COUPPEY DE LA FOREST.

Direct Examination by Mr. Todd.

My official residence, Paris, France; my title, "Sec'y of the Commission d'etudes des eux," Paris France, and have been connected with the Government of the City of Paris for four years.

4929–4831 Description of the irrigation system of Paris.

4831 The effect upon the inhabitants who use the water from the irrigation field, showing no typhoid, cholera or dysentery.

4832 The purification of the Seine takes place 35 miles below Paris.
4833 Number of people discharging sewage into the Seine, 1,300,000.
4834 Cost of irrigation fields.
4836 Discharge flow of the Seine.
4840 Revenue returns from the irrigation fields.
4840 Example of a woman who contracted a disease from salad.

4903 ARTHUR W. PALMER.

Direct Examination by Judge William M. Springer.

Professor of Chemistry in University of Illinois. Studied
4903 chemistry in Berlin and Gottengen; have been a water chemist for twenty-two years.
4919 Volume of flow of the Illinois and Mississippi Rivers.
4939–5026 Table of analyses.
5040 Table of averages for 1899.
Table of averages for 1900.

The average flow in the Illinois and Michigan Canal to 1900 was from 35,000 to 36,000 cubic feet per minute. In 1900 it varied during the year, but the average was 26,700 cubic feet a minute. In 1901 the pumps were in operation only during seven months, beginning the latter part of April and reaching to the latter part of November. During this period of seven months the average rate at which liquid was raised from the south fork of the Illinois and Michigan
Canal was 23,000 cubic feet per minute, the average for the
5141 entire year, which is not a true average, however, for the time of operation, being 13,800 cubic feet per minute.

An act to establish a chemical survey of the waters of the State of Illinois, approved June 7, 1897, and endorsed July 1st,
5156 1897.

Q. Professor, I now call your attention to tables 1 to 4, inclusive, which contain the chemical examinations of water from Lake Michigan during the years 1897 to 1900, inclusive. Will
5357 you please state what significance as a chemist you attach to these tables for the examinations of the waters of Lake Michigan?

A. The date of the analyses shows the general character of the water of Lake Michigan and a comparison for the different years and averages for the different years with each other show that the water of the lake is subject to no great variations as to the proportion of the various substances which are determined in the sanitary chemical an-

alyses: * * *. The sediment being in the main such as is natural to any considerable body of surface water, but including, also, a certain amount of refuse from the city and of dredging from the Chicago River. The variations in no case vary considerably, and on
5358 the whole the water of the lake is to be considered as superior in quantity to the water of all of the larger streams of Illinois and the vicinity

Mr. Jeffries' Objection to Averages of Chemical Results Has
5361 Been Deceptive.

Chemical Results of the DesPlaines River at Lockport.

5368 Table No. 8, Showing Chemical Examination of the Waters of the Illinois River at Morris.

5374 Yearly Averages Comparing the Average of Chemical Constituents for Four Years Prior to 1900 with the Year 1900.*

Table of Averages Based Upon the Chemical Examination of the
5381 Water of the Illinois River at LaSalle, Showing a Comparison of Four Years Prior to 1900 with the Year 1900.

In periods of low water the channel (Illinois and Michigan Canal) often carried the entire body of Chicago sewage past Joliet and discharged it at various points many miles below that at which it
5383 is now delivered into the river, thus carrying the pollution much further down stream than the points at which it is now found.

Since the opening of the main drainage channel the diluted sewage which enters the stream between Lockport and Joliet is mainly carried by the DesPlaines and Illinois rivers, and the volume discharged by the canal at points below Joliet constitutes a much smaller proportion of the volume of the river. Moreover, the water of
5383 the channel is now in far better condition, because of its great initial dilution at Joliet and the more thoroughgoing natural purification thereby occasioned.

It is evident from the comparison of these averages that the proportions of these organic matters contained in the waters of the Illinois River at LaSalle have been considerably reduced as a result of the greater dilution produced by the opening of the Chicago main

*This comparison shows that the chemical constituents of the water showing the presence of organic matter was greatly in excess during the four years prior to the opening of the canal, in the year 1900.

drainage channel. That the proportions of nitrogen as nitrites
5384 is no less than one half what it was before the opening of the Drainage Canal, while the proportion of nitrogen as nitrates are slightly less than they were before that opening.

Table of Averages No. 8 at Averyville, Making a Comparison of Three Years Before the Canal Was Opened with Two
5384 Years Since the Canal Was Opened.

The study of the data of the analyses, and particularly comparison with those for the other points along the river between Averyville and Lockport, show unmistakably that a very great purifi-
5385 cation of the waters of the stream takes place as they flow along the 125 miles of its course between these two points.

* * *

It is very noticeable that both before and since the opening of the Chicago main drainage channel the proprotions of free ammonia are much greater in cold weather than at other seasons. And it is evident, too, that the proportions of free ammonia contents in
5386 the water of the Illinois River at Averyville are much less since the opening of the Chicago main drainage channel than they were before that time.

Comparison of the figures of table of averages No. 8 shows that as a result of the dilution effected by the opening of the Chicago main drainage channel, or at least subsequent to that opening,
5387 the proportions of the various significant constituents of the water of the Illinois River at Averyville are very greatly reduced.

Comparison of the averages for Averyville with those for the tributary streams serve to show that the waters of the Illinois River at this point contain considerably less organic matter than are contained in the waters of its chief tributaries, which latter have never been in contact with Chicago sewage, although, of course, they receive some sewage from comparatively small towns. It is very evident, of course, that free ammonia and nitrites are still present in the waters of the Illinois River at this point in greater quantities than are contained in most of the tributary streams, but the considerations detailed above and all available data show unmistakably that the character of the water in the streams at Averyville is now far better than it was before the Chicago sewage received its initial dilution at Chi-
5389 cago and not at the junction of the DesPlaines and Kankakee rivers, sixty miles nearer to the point now under consideration.

It is my opinion that the animal matters discharged by the two

canals, the Chicago main drainage channel and the Illinois and Michigan Canal, into the DesPlaines River in the vicinity of Lockport and Joliet, and discharged by the DesPlaines into the Illinois River about ten miles above Morris have been entirely destroyed before the waters of the Illinois River reach Averyville and the substance of said animal matters have been in part converted into mineral substances and in part built up into the substances of living vegetation; this opinion being based upon my study of the waters of the streams in
5390 question at the various points enumerated in my testimony in this case, and upon the evidence of the chemical analyses which have been introduced as part of my testimony.

Table of averages No. 9 at Havana, wherein four years before the opening of the canal is compared with the averages for
5391 three years after the opening of the canal.

Table of averages at Kampsville, comparing three years before with three years since the opening of the Drainage Canal.

Comparison of the averages for the two and three years periods makes evident the great diminution in the proportions of the various constituents except free ammonia, which is .393 parts per
5396 million in the later period, as against .371 parts per million in the earlier period, and the nitrates, which have very considerably increased.

Table of discharge in cubic feet per second from Kampsville.
5406–5424 Time, from 1996 to 1902, inclusive.

Table of averages based upon chemical examinations of the
5426 waters of the Illinois River and the Mississippi River at Grafton for the four years before and three years since the opening of the Drainage Canal.

The quantities of the water, that is, the proportional quantities of the Illinois River water and the Mississippi River water have been calculated for the average contents of chlorine for the year for each one of the five points in the cross-section. They show that comparatively little of the water of the Illinois River reaches the Missouri side of the Mississippi at this point (Alton). For the year 1899 2.4 per cent. of the water near the Missouri shore came from the Illinois River; the other 97.6 per cent., consisting of the water from the upper Mississippi at the point one-fourth the distance from the Missouri shore, the Illinois River water amounted to 4.8 per cent., while the Mississippi River water was 95.2 per cent. of the mixture. At the mid-stream, that is, a point midway between the two points, the proportion of Illinois River water was 11.3 per cent; that of the Mississipp, that is, the upper Mississippi River water, was 88.7 per

cent. At a point one-fourth distance from the Illinois shore, the Illinois River water amounted to 23.5 per cent., while the Mississippi River water amounted to 76.5 per cent. Near the Illinois shore the Illinois River water predominated, amounting to 30 per cent. of the water passing down at that point, the Mississippi River water constituting 62 per cent. of the mixture. For the year 1900 similar figures appear, except that there was a little more of the Illi-
5453 nois River water towards the Missouri shore, the percentage being 4 per cent. Illinois River water near the Missouri shore, 96 per cent. upper Mississippi River water.

Q. State whether the mixing of the waters of the Illinois and Mississippi rivers is complete by the time they reach the mouth of the Missouri River.

A. From certain analyses of samples of water taken in the Mississippi River about one-half mile above the mouth of the Missouri River, it is my opinion that the mixing of the water of
5454 the Illinois with the water of the Mississippi is by no means completed by the time these bodies of water reach the mouth of the Missouri.

Q. Would it be practicable to calculate the mixing of the waters of the three rivers at the Chain of Rocks from the proportion
5454 of free ammonia?

A. It would not, because free ammonia changes sometimes rapidly, sometimes slowly, etc.

Q. Would it be practicable to calculate the proportions of the waters of the three years from the propositions of nitrites?

A. It would not, for reasons similar to those just stated with reference to the ammonia. As to solids, it might be in case the proportions of total solids were sufficiently different in the three
5455 streams which were coming together, and suspended matters would also be unsatisfactory for the reason just stated in regard to total solids.

There is no certainty, and in this particular case there would be no certainty, that the quantities of suspended matters found in the water of the Illinois at Grafton would proceed down through the Mississippi River to the St. Louis water-works. There is no certainty that the quantities of suspended matters contained in the waters of the Mississippi above the mouth of the Illinois would remain in these waters until such time as this body of water reaches the intake of the St. Louis water-works, and there is no certainty that such suspended matters in the waters of the Missouri River above its junction with the Mississippi remain until it reaches the intake. The calculation

based upon the suspended solids and upon the total solids which include suspended solids have no sound basis in fact, and, on the other hand, at times the body of water passing down the bed of the Mississippi above the mouth of the Missouri, may, between the mouth of the Illinois and the mouth of the Missouri, back up and hold in suspension matters which would then be in excess of the quantities found in the waters of the Illinois and of the Mississippi at and above Grafton. Hence, in my opinion, it is totally impracticable to cal-
5456–57 culate the respective proportions of waters from these sources contained in the mixture passing down from the Mississippi River past the intake tower of the St. Louis water-works.

The Fox River is the largest tributary of the Upper Illinois proper and next to that of the Kankakee its discharge is the most important diluting factor of the Upper Illinois. Its discharge is more uniform in volume than that of the Desplaines River, and is greater in proportion to its watershed area. * * * The waters of the Fox are rather highly charged with organic matters which are mainly derived from the vegetation which is abundant in this stream, particularly in the marshes and shallow lake which constitutes the chief source of its head water supply. The stream receives the sewage and manufacturing wastes of a number of towns of which Elgin, with a population of 22,433, and Aurora, with a population of 24,147, are the largest. Between these two towns is the town of Geneva, where there is a large glucose works, and in which 40,000 carloads of corn are used annually, the waste from which—probably at least 150 tons of highly nitrogenous organic refuse daily—are discharged into the river.

5472 Duties as head of the Department of Chemistry, University of Illinois.

5474 Table of analysis of the water of the Big Vermillion River at La Salle. Yearly averages.

5476 Table of chemical analysis of the waters of the Spoon River at Havana.

5476 The Big Vermillion River described.

5476 Comparison of the detail data of the analyses of the water of the Illinois at Averyville and at Grafton with the data of the analyses of the waters of the tributary stream show that the latter are subject to seasonal variations which in most respects are as great as are those of the Illinois, * * * and the general averages for the six tributaries examined are substantially equal to the averages for the Illinois for 1901-2.

5477 Table of averages No. 15. Comparison of the waters of the Illinois with the waters of its tributaries.

5479 Chlorine charts showing seasonable variation in contents of chlorine in the waters of the Illinois River during the years

5483-4 '96 to 1900.

Oxygen consumed. The lines representing the oxygen consumed, both the total and that consumed by the filtered water show marked diminution between Lockport and Morris, a considerable and somewhat continuous diminution from Morris to Havana, beyond which point the total oxygen consumed increases slightly, so that the proportions required by the waters discharged from the Illinois into the Mississippi at Grafton are greater than they were at either Averyville or Havana, this being in part due to the luxuriant growth of vegetation in the lower stretches of the river, and in part due to the presence of other suspended matters, silt and so on, which during a portion of the year are more abundant in the lower stretches

5486 of the river than they are further up.

Nitrites. Comparison of the proportions of nitrogen as nitrites shows that before the opening of the drainage canal there were but exceedingly small proportions contained in the water at Lockport, but noticeably greater proportions at Morris, the maximum being reached at La Salle, for while the proportions of nitrites below this point are always considerable there is continuous diminution all the way down to the mouth of the river at Grafton.

Nitrates. The lines representing the proportion of nitrates as we proceed from Lockport and Joliet to Morris and so on to La Salle show a remarkable increase in the proportions contained. The increase of nitrates between Joliet and Morris is due in part to the fact that the waters of the Kankakee River, which unite with those of the Desplaines between these two points, are in certain seasons very highly charged with nitrates, but much of it is undoubtedly due to the activity of the nitrofying organisms which in this stretch of the river appear to find the conditions of food supply and dilution most propitious.

5487 The great increase of nitrates between Morris and La Salle must be regarded as practically entirely due to the nitrofying process, which in this stretch of the river completes the destruction; that is, the oxidation of the organic matters discharged into the river in the Chicago sewage at Lockport and Joliet. From La Salle to Averyville there occurs a very considerable increase in the proportion of nitrates. This is due not to dilution, for no considerable dilution occurs between these points, but to the utilization of nitrates by the

vegetation, which is exceedingly abundant in the broad lake-like reaches between these points. * * * With respect to these differences in the proportions of nitrates between the two periods in question, it seems evident that the conclusion to be drawn must be that nitrification now takes place at least as completely, and it would seem far more completely, than before the opening of the drainage canal.

5488 Comparisons of the curves from the period of '97 to '99 with the curves for 1900 shows how great an effect the dilution produced by the opening of the drainage channel has had, and shows that this effect extends to the mouth of the Illinois River. The fact that the total organic nitrogen and the nitrogen as albuminoid ammonia do not decrease below Havana is undoubtedly due to the presence of the enormous masses of vegetation in the waters of the lower river; that the free ammonia does not decrease below the proportions shown for Grafton is doubtless due to its continuous production through the decomposition of the various organisms constituting the plankton, which from time to time complete their life cycles and have their substances then to enter upon that universal series of transformations to which all organic matters are subject.

5490 Chart showing stages in the Illinois River, the Mississippi River and the Missouri River from July, 1899, to July, 1900.

5495 Explanation of stages of the three rivers about January, 1900, as based upon the chart.

5506 Chemical composition of the Missouri River the latter part of January and the early part of February, 1900.

While my data with respect to the composition of the waters of the Missouri River at this time are not as enormous as those which I have described concerning the composition and the constituents contained in the waters of the Mississippi and the Illinois, the result of these analyses show similar fluctuations, and by reference to the data submitted in this case on behalf of the complainant in the case—that is, the tables of results of chemical analyses of waters of the Missouri River made by Professor Teighman—we find that his results fully corroborate my own with respect to these conditions in the Missouri River water, and being more enormous than my own, having been taken daily in the Missouri River, afford a series of determinations which, compared from day to day with those which I have obtained from the waters of the Illinois and Mississippi Rivers, show even more conclusively than do my own more meager data for this period, a more considerable conformity between the condition of the waters of the Missouri River and the Mississippi River at this

time; that is, the complainants' data for this period show a worse condition in this respect in the waters of the Missouri River at Fort Bellefontaine than do my own enormous data, for the reason that they cover the period more fully, and they show complete conformity with the conditions I have already stated with respect to the
5510 Mississippi River.

Q. Have the waters in the lower stretches of the Illinois River been more greatly charged with organic matters since the opening of the Chicago drainage canal than they were prior to the opening of the canal?

A. They have not.

The data to which I have testified and the various plates representing different proportions of the data, particularly those referring to the condition of the water in the Illinois River at Kampsville and at Grafton, and testified to somewhat in detail heretofore by me, show that the waters in the lower reaches of the Illinois River are now, since the opening of the Chicago main drainage channel, less charged with organic matter than they were previous to that
5511-12 opening.

5515 Tables of cross sections at Averyville, No. 1.

5516 At Grafton, No. 2.

5518 At Hartford, No. 3.

5520 At Chain of Rocks, No. 4.

Defendants' special cross section sheet, No. 3, containing data of the analyses of cross section samples collected in the Mississippi River at Hartford one-half mile above the mouth of the Missouri River, which samples were collected December 6, 1899, and July 7, 1900, and August 17, 1900, show that the waters of the Mississippi River have not commingled perfectly with the waters of the Illinois River by the time these two bodies of water have reached this point where they are about to come in contact with the waters of the Missouri River, and show that even down to this point the waters of the Illinois River pass down mainly along the Illinois shore, while the water passing down near the Missouri shore is mainly the water of the upper Mississippi River. The cross section of the Mississippi River taken two miles below the mouth of the Missouri River merely affords evidence of the commingling of the three bodies of water at this point and is corroborative of the more extensive series of cross section analyses which have heretofore been testified to.

5524 I have made a great many special collections of data with regard to water. I have got everything that is published so far as I know and have studied it at various times. I made also

special collections of water from the Illinois River at Grafton for the purpose of noting whether the compositions of water varied at different times in the day—that is, during twenty-four hours; and I have that data here on sheet No. 5, special collections.

5525 I was again, as professor of chemistry of the University of Illinois, in charge of the chemical survey of the waters of the State of Illinois, with which duty I have been charged by the president and trustees of the university, and acting under the pro-
5528 visions of the act of the legislature before cited in this case.

5530 Collections for 1901.

5531-5558 incl. Tables of analyses.

Plate No. 101, series No. 1901, A. W. P., represents the averages for the period of three months of October, November and December, 1901, and those for the same three months in 1899 in parallel column. The comparison of the three rivers—the Missouri, the Mississippi and the Illinois—exhibits a very great difference between the Illinois and the Missouri under one heading and the Mississippi under the other during the period in question. * * *

The significance of these features is determined upon the fact that we have demonstrated elsewhere that the water of the Illinois does not mix perfectly with the waters of the Mississippi on its way from Grafton down to the chain of rocks, and that the Illinois River flows mainly close to the Illinois shore, while the water near the Missouri shore consists mainly of Mississippi River water mixed only slightly with Illinois River water, though at mid-channel there is more or less considerable mixing of the waters of the two streams. That these conditions prevail down to the mouth of the Missouri River, the Missouri River water, as it enters the Mississippi deflects the Mississippi River water, forcing it towards the Illinois shore and it passes down chiefly towards the Missouri shore. It mixes, of course, to some extent with the fluid coming down from the upper Mississippi at this point, but it is substantially but slightly mixed Mississippi River water which is towards the Missouri shore; that is, the main body of water from the Illinois River is towards the Illinois shore, and it is water of the Mississippi River mixed with but small proportions of the water from the Illinois, which comes into immediate contact with the discharge from the Missouri River when the Missouri River water enters the bed of the Mississippi, and it is quite unlikely that any considerable proportion of Illinois River water mixes at first with the Missouri River water, but rather it is mainly Mississippi River water, containing but a small proportion of the water of the Illinois River.

What we have then briefly stated is, first, a body of Missouri River water passes down the west or Missouri bank; second, the mixture of Mississippi River water with Missouri River water containing but a very slight proportion of Illinois River water; third, Mississippi River water containing more Illinois River water in the middle; and fourth, Mississippi River water mixed with a more considerable portion of the water of the Illinois River; and fifth, near the Illinois shore the larger proportion of Illinois River water mixes of course with the Missouri River water and to some extent
5561 also with the water of the Missouri River.

Upon chart 102 of this series there are represented the proportion of oxygen consumed or required by the waters of the Illinois River at Grafton, the Mississippi River at Grafton just above the mouth of the Illinois, the Missouri River at Bellefontaine just above its mouth, and the Mississippi River at four different points across the stream opposite the St. Louis waterworks intake at the chain of rocks. A comparison of the three rivers shows at once that the total oxygen required was much greater in the Mississippi River water than in the Illinois, and was still greater in the Missouri River water than in the Mississippi.

5562 Comparison of the three rivers shows too a considerable improvement of the Illinois River in 1901 as compared with its condition in 1899, and an improvement too in the Mississippi River in 1901 as compared with its condition during the same period of 1899, while the conditions in the Missouri River were worse during this period in 1901 than they were in the same period in 1899.

5563 A comparison of the data at the chain of rocks, where we note the relative quantities of the suspended matter at the four different points across the stream, shows at once that there is far less mixing of the Illinois River water with that of the Mississippi and that of the Mississippi with the Missouri in 1901; that is, after the opening of the Chicago main drainage channel than there was in 1899, the season just preceding the opening of the drainage
5565 channel.

The solid matters in solution both at the different points at the chain of rocks and in the three separate rivers are shown upon chart No. 108. The features exhibited with this chart show again that between the mixtures of the Illinois River water and the Mississippi River water which is passing along the Illinois shore and the Mississippi River water which hugs the Missouri shore is a body of water existing chiefly of upper Mississippi River water which intervenes between that coming down the Illinois shore and the body

passing down past the intake tower and the Missouri shore, and substantially prevents the Illinois River water from reaching the body of water which enters the intake of the St. Louis waterworks.

Q. Professor, have the proportions of organic matters in the Illinois River near the mouth been greater or less since January, 1900?

5567 A. They have been less.

Table of proportions of total organic nitrogen in the water of the Illinois River at Kampsville, based upon monthly averages for the years '97 to 1900, both inclusive, shows a decrease since the opening of the canal over conditions that obtained prior to the

5568 opening of the canal of 17.48 per cent.

Dissolved organic nitrogen for the same period shows a de-

5569 crease of 17.92 per cent.

Quantities of nitrogen in the water of the Illinois River. Tons discharged for twenty-four hours, calculated from monthly averages of flows and constituents, show a decrease of 25 per cent. for the same period.

5570 Nitrogen as free ammonia for the same period shows a decrease of 6 per cent.

5571 Nitrogen as nitrites for the same period shows a decrease of 40 per cent.

5572 Nitrogen as nitrates for the same period, 15 2-3 per cent. increase.

5573 Suspended albuminoid ammonia for the same period a decrease of 19 per cent.

5574 Q. Professor, are the quantities of organic matters in the Chicago sewage discharged into the Desplaines River less or greater then, since the opening of the Chicago drainage channel than prior to that opening?

5575-75 A. They are greater since the opening of the Chicago main drainage channel than they were prior to that opening.

Quantities of organic matters in the Chicago sewage discharged into the Desplaines River since the opening of the Chicago drainage canal and prior thereto, with the analytical data and the discussion of the methods by which the same was arrived at in ton measurements, and a comparison between the Illinois and Michigan Canal at Lockport and the main channel.

5575-78 inc. Table of monthly flow in the Illinois and Michigan canal for the year 1900.

5580 Table 22. Quantities of nitrogen discharged into the Illinois River in Chicago sewage. Nitrogen as free ammonia dis-

charged into water of the Illinois and Michigan canal and the sanitary canal. Tons for twenty-four hours.

5585 Table 23. Quantities of nitrogen discharged into the Illinois River in the Chicago River. Total organic nitrogen discharged into waters of the Illinois and Michigan canal and the sanitary canal. Tons for twenty-four hours.

5588 Table 24. Quantities of nitrogen discharged into the Illinois River in Chicago sewage. Total nitrogen—i. e., some of the nitrogen as free ammonia and the total organic nitrogen discharged by the two canals. Tons for twenty-four hours.

5589 Q. Professor, have you any data which shows the quantities of organic matter in the Illinois River near its mouth prior to the opening of the canal and since that time?

A. I have. I have the data in tables similar to those which we have just been discussing, and which refer to the Illinois and Michigan canal and the Chicago main drainage channel, and in addition I have some plates upon which there are lines drawn which show graphically the relative proportions at the different seasons of the year and at different points along the streams in question. The tables are numbered 4 to 9, both inclusive.

5590 These tables, numbered, 4, 5, 6, 7, 8 and 9, of this series, mean daily discharge of nitrogen in the form of free saline ammonia; in the form of albuminoid ammonia, the total organic nitrogen and nitrogen as nitrites and the nitrogen as nitrates in the waters of the Illinois River discharged from the Kampsville dam for the years '97 to 1902, inclusive, and also show the average discharge for twenty-four hours for the first six months and the second six months in each year referred to and the average discharge for the entire year; also the average discharge for the period of three years prior to 1900 and for the three year period 1900, '01 and '02, inclusive, thus covering the three year period immediately preceding the opening of the Chicago main drainage channel and the three year period immediately subsequent thereto.

5592 The computation of these quantities have been made in similar manner to the computations of the quantities of nitrogen discharged by the Illinois and Michigan canal and by the sanitary canal into the Desplaines River. That is, the computations have been made from the mean daily flow of water from Kampsville dam and the average contents of the constituents for the months in question; the mean daily flow for the first six months, that for the second six months and that for the year and the average contents of the respec-

tive constituents for the first six months and the second six months and the entire year.

5593 Table No. 14. Total organic nitrogen. Quantities of nitro-
gen in the waters of the Illinois River at Kampsville. Tons
5595 discharged for twenty-four hours.
5597 With accompanying chart.

Comparisons of the lines upon the plate with each other, which merely represent the date, which have been introduced, show that at times there is six times as much total organic nitrogen discharged into waters of the Illinois River from the dam at Kampsville as is contained in the water of the Desplaines River at Joliet, which latter comprises the mixture of the flow from the upper Desplaines, that from the Chicago main drainage channel and that from the Illinois and Michigan canal.

5598 Table No. 5 of this series shows the quantities of nitrogen in the water of the Illinois River. Tons discharged for twenty-four hours calculated from monthly averages of flow and constituents. Albuminoid ammonia at Kampsville shows a decrease of 30 per cent. for the second three year period over the first three year period.

5605 Table No. 6. Tons of free ammonia.

5607 Table No. 7. Quantities of nitrogen in the waters of the Illinois River at Kampsville show a decrease of 42.5 per cent. from the first period to the second three year period.

Table No. 8. Quantities of nitrogen as nitrates in the waters of the Illinois River at Kampsville. Tons discharged for twenty-four hours.

5610 Table No. 9. Quantities of nitrogen in the waters of the Illinois River at Kampsville. Tons discharged for twenty-four hours from yearly averages of flow and constituents.

5612 Table No. 10. Quantities of nitrogen in the waters of the Illinois River at Kampsville. Tons discharged for twenty-four
5613 hours.

Table No. 11. Quantities of nitrogen in the waters of the Illinois River at Kampsville. Tons discharged for twenty-four hours from second six months averages of flows and constituents.

5614 Table No. 12. Quantities of nitrogen in the waters of the Illinois River at Kampsville. Tons discharged for twenty-four hours. Yearly averages calculated from the discharges in tons for each month.

5615 Table No. 13. Quantities of nitrogen in the waters of the

Illinois River at Kampsville. Tons discharged for twenty-four hours. Tons discharged calculated from yearly averages of flow and yearly averages of constituents.

5616 Tables of mean daily flow in cubic feet per second from Kampsville dam.

5617-5620 incl. Table No. 14. Quantities of nitrogen in the waters of the Illinois River at Kampsville. Tons discharged for twenty-four hours calculated from the average flow for each period of three years and the average proportion of the constituents for the same period.

The evidence shows conclusively that since the opening of the Chicago main drainage channel there has taken place not only a considerable diminution in proportion of the organic matters contained in the waters of the lower Illinois River, and as they are about to discharge from that stream through the Mississippi, but that a substantial decrease of the actual quantities of the organic matters contained in these waters has occurred, and this notwithstanding the fact which I have testified to already, that the quantities of organic matters conveyed into Chicago sewage in the Desplaines and thence into the upper Illinois are considerably greater now than they were before the opening of the Chicago main drainage channel. As it has been shown in my testimony that the organic matters contained in the Chicago sewage discharged into the upper Illinois are practically discharged or converted into vegetable matters by the time the waters reach Peoria, that is, Averyville, where another great influx of sewage and other organic wastes occur, it will be of importance to compare the condition of the water at Averyville just above Peoria with its condition at Kampsville, 140 miles below, with respect to the quantities of organic matters carried by the stream at these two points. The data involved in this comparison have been brought together under table 15 of this series, which is as follows:

5623 Table No. 15 represents the quantities of nitrogen in the waters of the Illinois River at Averyville above Peoria. Tons discharged for twenty-four hours, that is, the average for the years 1897 to 1901, inclusive, with the general averages first for the three year period before the opening of the Chicago main drainage channel; second, for the two year period immediately following; and also there are introduced once more for purposes of comparisons similar data with respect to Kampsville. Comparing the averages for the three year period before the opening of the Chicago main drainage channel with the average for the two year period subsequent thereto. * * * Comparisons of the general averages for these

two periods show that subsequent to the year 1899 there was a decrease in the weight of nitrogen as nitrites discharged by the waters of the Illinois River at Averyville from 5.24 tons per twenty-four hours to 2.34 tons per twenty-four hours, a decrease of 55 per cent.

* * *

Comparing the data for Averyville with those for Kampsville for the years 1897 to 1899, inclusive, the data for Kampsville having been taken in evidence, shows that between Averyville and Kampsville there is a very considerable decrease in the quantities of nitrites carried by the waters of the Illinois River, these amounting to 48.47 per cent.; that the nitrogen as nitrates during this period increased 14.5 per cent.; the nitrogen as free ammonia decreased 43.56 per cent.; the total organic nitrogen as determined by Kjel Dahl process increased 62.15 per cent., this increase being due to the organic matters brought in by the various tributaries of the Illinois, the discharge of the organic matters at Peoria and Pekin and the wash from the immediate watershed of the river and including the vegetation of the river, which has subsisted upon refuse organic matters introduced at points above and from the conversion of mineral matters contained in the water, including nitrites, nitrates, free ammonia, carbon, etc. In the substances of the vegetation which is so luxuriant in the lower reaches of the Illinois, the total nitrogen is found to increase 7.47 per cent. during this period between Averyville and Kampsville. The albuminoid nitrogen increased between these two points to the extent of 44.39 per cent., considerably less in proportion than did the total organic nitrogen. The oxygen consumed by the waters increased in quantity between these two points to the extent of 45 per cent.

Comparing the periods after the opening of the Chicago main drainage channel and for the purpose of putting this comparison upon a more reasonable basis, I have calculated an average for the content, that is, the quantity, of these constituents contained in the water of the Illinois at Kampsville for the two year period prior to the opening of the Chicago main drainage channel, since we have data for Averyville only for this period, and we find generally as follows:

A decrease in the quantities of nitrogen as nitrites from 2.34 tons for twenty-four hours at Averyville to 1.22 tons for twenty-four hours at Kampsville, a decrease of 47.85 per cent., which is almost as considerable a percentage as a decrease between these two points in the earlier years, while the actual quantities themselves are one-half of the quantities contained in the water at these two points during the previous period; that is, the three years prior to the opening of the Chicago main drainage channel. The nitrates show a

change between Averyville and Kampsville; that is, a decrease amounting to 5.49 per cent., while in the former period between these two points there occurred an increase in the weight of nitrogen as nitrates. * * *

5625 A comparison of the data for Kampsville with those at Averyville shows that at the like periods which have been referred to the actual weight of nitrites and of free ammonia carried by the waters of the Illinois decreased more than 40 per cent. during the flow from Averyville to Kampsville. Inasmuch as the waters of the tributaries of the Illinois contained organic material in proportions equal to those of the Illinois itself, and since enormous quantities of nitrogenous organic matters are discharged into the Illinois at Peoria and Pekin, a few miles below Averyville, a considerable increase in the quantities of nitrogenous organic matters in the waters of the lower Illinois might well be expected, but it is to be remembered that the organic matters in the waters of the Illinois below Havana, forty-five miles below Peoria and eighty-eight miles above Kampsville, consists of vegetable matters, chiefly those of plankton, as is shown by observation and by the results of the general inves-

5627 tigations which have been introduced in evidence.

By the term "organic matters," I mean such matters containing carbon in combination as constitute the tissues of living things or organisms, and are contained in the various secretions or liquids contained in living things of all sorts, great and small, and some of the products elaborated by living organisms, excreted by them, or built up into their living tissues, excluding the carbon di-oxide, which is excreted by certain living organisms and absorbed and utilized by other living organisms, but which is commonly regarded as mineral or inorganic substance.

By the term "nitrogenous organic matter," I mean to designate those organic matters which contain the element nitrogen as an essential constituent. Not all organic matters contain this element, but the tissues of living things all contain or in part consist of organic matters of which nitrogen is an essential element. Such matters as the substance of flesh, the proteate bodies, stirred up in the seeds of plants known as gluten and so on, and other substances contained in the juices and secretions of living organisms, which are organic in character, and which contain nitrogen as an essential constituent. There are certain nitrogenous organic matters secreted in plants and animals of which the best example perhaps is the urea excreted by animals in the urine, which contribute in partial proportion to the nitrogenous organic matters contained in sewage.

By the term oxidation, I mean the combining or uniting of oxygen with the various organic matters contained in the water, and in a general way, also, the union of the elements of water possibly, with these organic matters, which latter is frequently called hydrolosis. The effect of this oxidation being, in general, to convert the organic matters into substances which are regarded as inorganic or mineral in character.

The chief agencies in bringing about oxidation of organic matters in sewage are the living organisms present in the water, particularly

those of the minuter forms, and which are commonly referred

5628 to as bacteria.

By the term "nitrification," as I have used it in my testimony, I understand such oxidation of the nitrogenous organic matters contained in the water as results in the conversion of the nitrogen of these matters into nitrite and nitrates; that is, essentially finally into saltpetre and nitre. Complete conversion of the nitrogenous matters

that have undergone nitrification into mineral substances which

5629 comparatively are innocuous.

The turbidity of water is due to or consists in a certain appearance of cloudiness and partial opacity, which result from the water containing matters in suspension. The color of the water is distinguished from turbidity in that it results from the presence of colored matters in solution. A water may be quite clear and transparent, but have a decided color, and it may, on the other hand, be both turbid and colored. One is not necessarily associated with the other. Suspended matters, which make a water turbid, may impart also a color to the water, but such color is removed by such filtration as takes out these suspended matters.

By total solids we mean all solid matters which are contained in solution and in suspension in the water, which matters are generally determined together as total solids, by evaporating a measured portion of the water to dryness, so that the water itself is expelled. The residue thus obtained is designated as the residue on evaporation or the total solids. By loss of ignition we mean the loss in weight which takes place when the total solids or residue on evaporation is gently ignited, that is, heated to dull redness, the loss resulting from this ignition is due to the partial burning away of organic matters, and to the loss of certain inorganic substances, and to the votalization of certain inorganic substances or constituents of the residue. No very great significance attaches to the loss on ignition to-day for the reason that it is not practical to distinguish accurately between such loss, as due to the destruction and removal of organic matters from the

loss of inorganic constituents, as water, carbon di-oxide, oxygen from nitrates, salts of ammonia, and so on. The significance attaching to the determination of total solids or residue on evaporation lies in the fact that too great a quantity of such matters contained in water render it unsuitable for domestic purposes or for manufacturing or steam-making purposes.

By the term "oxygen consumed," we mean the quantity of oxygen that the substances contained in the water absorb or unite within the chemical process used in making this determination. The quantity of oxygen consumed is an index to the quantity of organic matters contained in the water and affords information concerning the character, or, I might say, in some measure affords information concerning the character of the organic matters contained, that is, some organic matters required more, or combined with more oxygen under conditions of the determination than do others. If a considerable quantity of oxygen is required or consumed by the substances in a given water, the reasonable inference is that a considerable quantity of organic matters is contained. If, on the other hand, a small quantity of oxygen is required or consumed by the substances in a given water, the reasonable inference is that the quantity of or-

5631 ganic matters contained in that water is correspondingly small.

Nitrogen as nitrites as recorded in the results of the sanitary chemical water analyses refer to the nitrogen contained in combination with oxygen and other substances and constituting salts, which are called nitrites. They are derived in part from the air, being washed from the air usually in the form of nitrites of ammonia by falling rain. They are also derived from the leechings of soils and earth strata with which the fallen rain on its way to the streams come in contact. They are formed, moreover, in the oxidation of the various nitrogenous organic matters which have been referred to above in my testimony, both those lying upon the surface of the ground or contained in surface soils, in the streets, in barn-yards, in the fields, and from similar changes taking place in the nitrogenous organic matters contained in the water of streams and lakes and ponds; both those derived from or contained in nitrogenous vegetable matters of all descriptions and nitrogenous animal matters, such as are contained in the wastes of habitation, including sewage, barn-yard wastes,

5633 and various manufacturing wastes.

Nitrogen as nitrates, as recorded in the results of the sanitary chemical analyses of water, represents the quantity of nitrogen that is in combination with basic matters and oxygen, the latter in greater proportion than is contained in the nitrites above referred to. The

nitrates, like free ammonia, and nitrites are at times derived in part from the air, being washed from the air by rain, and so carried to the earth. They are derived also from the earth strata with which the rain comes in contact and over which or through which it flows
5634 on its way to the streams or into the great body of ground water.

Q. Professor, is it possible to form a reasonably accurate judgment of the condition of a given water from a consideration of any one constituent determined in the sanitary chemical analysis?

A. No reasonably fair judgment regarding the sanitary condition or the potability of a water can ordinarily be drawn from the consideration of any one single constituent determined in the sanitary chemical anlysis of a water, but all must be considered together, and with full knowledge of the source of the water, and of the substances contained in it, and the conditions of time and place and environment, season, and so on.

The fact that a greater volume of water passes from the Kampsville dam for the period prior to the opening of the Chicago drainage canal than for the period since and the explanation of
5637 the same.

Q. Professor, wherein does the real value of your data concerning the composition of the waters of the Illinois River
5638 before and after the opening of the Chicago drainage canal lie?

A. Touching the questions at issue in this case, the real value of the evidence which I have introduced in this case in the way of analytical data lies in the comparison which it institutes between the period prior to the opening of the Chicago main drainage channel and the period subsequent to that opening. For the reason that the various determinations, so far as they themselves were concerned, and including the collections of the samples, were made under precisely the same conditions throughout both periods, and that they afford data which are strictly comparable and which show the conditions prevailing in the waters of the streams in question before and after the great change which was co-incident with and produced by the opening of the Chicago main drainage channel.

Q. Taking into consideration the conditions which exist upon the watershed of the Illinois River, and also the numerous chemical analyses of the waters of the Illinois River which you have made and about which you have testified in this case, what effect, in your opinion, has the opening of the Chicago drainage canal in January, 1900, had upon the waters of the Illinois River, and especially upon

those waters at Averyville, just above Peoria, and at Kampsville, near the mouth of the river, and at Grafton?

A. Taking into consideration my knowledge and information concerning the Illinois River, its tributaries, its water-shed, and the conditions prevailing upon and along the same, and taking into consideration the chemical examinations that I have made of the waters of the stream and its various tributaries, both before and after the opening of the Chicago main drainage channel, it is my opinion that the effect of the greater discharge of water resulting from the operation of the Chicago main drainage channel has greatly improved the condition of the water of the Illinois River along its course, rendering its waters less offensive to the senses in the immediate neighborhood of the point of discharge of Chicago's sewage into the Desplaines and thence into the Illinois, and reducing the proportions of the organic matters contained in the waters of this stream at Averyville and at other points along its course, and reducing the proportions of nitrogen as free ammonia and as nitrates, and reducing also the quantities of nitrogen as ammonia and as nitrites contained in these waters, and in reducing, not simply the proportions, but reducing also the actual quantities of the nitrogenous organic matters contained in the waters of this stream at various points, and particularly at Averyville, to all of which I have testified heretofore, in the evidence I have presented in this case; and with respect to Kampsville, I may refer to my testimony given above in this case, and state it as my opinion here, based upon the considerations enumerated above, that the condition of the water at Kampsville has been greatly improved co-incident with and as a consequence of the operations of the Chicago main drainage channel, in that my evidence shows a great reduction in both the proportions and the actual quantities of the most significant constituents of these waters as determined by the sanitary chemical analyses. And I base this opinion further upon the fact that since the opening of the Chicago main drainage channel, or sanitary canal, although the quantities of organic matters in the sewage discharged into the Desplaines and thence into the Illinois River are 30 per cent. greater than before that opening, the proportions of organic matters contained in the waters discharged by the Illinois River into the Mississippi are considerably smaller than they were prior to 1900; and that this decrease of the proportions is not a mere dilution is shown by the fact testified to by me, that the actual quantities of organic matters dis-
5641 charged are now less than they were formerly.

Q. From your knowledge of this subject and from your knowledge based upon the numerous investigations which you have

made, and about which you have testified in this case, what is your opinion as to the suitability of the waters of the Illinois River at its mouth, the Mississippi River just above the mouth of the Illinois River, and of the waters of the Missouri River, just before they enter the Mississippi River, for domestic purposes, and especially for use for drinking purposes?

A. From a consideration of my knowledge and information concerning these bodies of water, and a consideration of the results of investigations I have made of these waters, and the study of investigations made by others of these same waters, it is my opinion that neither the water of the Illinois River at its mouth, nor that of the Mississippi River just above the mouth of the Illinois River, nor that of the Missouri River just above its mouth, is suitable for domestic use; that is, particularly for drinking purposes without filtering, or without such treatment as shall render it sterile, as

3642 by boiling, or other means.

Q. Professor, from your knowledge of the conditions of the Illinois River and the water-shed of that river, and of the flow of the water in the river, the seasonal changes, the amount of sewage coming from the Chicago drainage canal, and from the amount of water from Lake Michigan which enters the drainage canal, and the sewage which passes through the drainage canal into the Desplaines and Illinois Rivers, and from the investigations which you have made of the waters of the Illinois River, both before the opening of the drainage canal and since that time, to which you have testified in this case, what effect, if any, in your opinion, has the opening of the Chicago drainage canal in 1900 had upon the waters of the Mississippi River as they flow along the eastern border of the State of Missouri, and has the opening of the Chicago drainage canal injuriously affected such waters so flowing along the eastern border of the State of Missouri for domestic, manufacturing and agricultural purposes, for use by the inhabitants living on the banks of said river, in the State of Missouri?

A. From the knowledge and information which I possess concerning these waters and the conditions existing in and about them, and the results of the investigations which I have made of these waters before and after the opening of the Chicago main drainage channel, and the knowledge I have of investigations of these same waters, made by others before and after the opening of the Chicago main drainage channel, it is my opinion that the effect of the increased flow secured by the opening of the Chicago main drainage channel has been at times to increase the flow of water in the Mississippi River along the western borders of the State of Illinois and the

eastern borders of the State of Missouri, and further, it is my opinion that the increased flow secured by the opening of the Chicago main drainage channel containing, as it does, increased quantities of organic matters derived from Chicago sewage, does not injuriously affect the waters of the Mississippi along the eastern borders of the State of Missouri, so far as the use of such waters for domestic, agricultural and manufacturing purposes is concerned, for the reason that the effect of the increased flow secured by the opening of the Chicago main drainage channel has been co-incident with or the cause of more complete destruction of the organic matters introduced into the upper Illinois River to such an extent that the waters discharged by the Illinois at its mouth contain less organic matters than they did prior to the opening of the Chicago main drainage channel, and further, for the reason that it is my opinion that the organic matters contained in the Chicago sewage conveyed into the Illinois River by the Illinois and Michigan canal, and the Chicago main drainage channel, so far as the sanitary chemical analysis can determine, are destroyed completely or converted into mineral matters and vegetable matter, which,
5643 as contained in such water, are practically innocuous.

CROSS-EXAMINATION,

By Mr. Jeffries.

Q. Is there anything in chemistry, so far as you know, which recognizes certain disease producing organisms in water as applied to running streams?

A. In my opinion, without the science of chemistry, without a recognition of the chemical changes or the significance of the chemical changes which disease producing organisms bring out, there would be no means of determining their presence or absence in running water, but the branch of science which is directly concerned in the utilization of chemical and other reactions for the purpose of determining the presence or absence of disease producing germs is, in my opin-
5647 ion, the science of bacteriology.

As a chemist, I doubt nothing except in the light of evidence
5648 which appeals to the experience and intelligence.

A chemist who concerns himself with the study of running waters, their pollution and purification, the seasonal variations to which they are subject, as to content and character of various substances, does recognize the fact that disease producing organisms and substances are introduced into running waters in sewage, and recognize as a fact that the quantities of such disease producing substances

and organisms may be greater or less at different points and at different times, although he, as a chemist, does not ordinarily determine the quantities of such disease producing organisms or
5649 substances.

Q. Is there anything in the science of chemistry which discloses the kind of nitrogenous matter in water which is of a disease producing character as separate and distinct from that nitrogenous matter which is not of a disease producing character?

A. The chemistry of toxins is an exceedingly important chapter of chemistry, and so far as concerns those disease producing substances which are called toxins, chemistry does determine the character of those substances and distinguishes them from other
5650 substances which are not disease producing.

It is my opinion that the averages based upon a given series of chemical determinations afford as accurate a basis for comparison and for determinations of certain facts as do the averages computed concerning the height of man in the determinations of the height of man or as the averages of the length of life of individual man and classes of men, and thus affords a reasonably accurate basis for
5667 conducting the business of life insurance.

Q. Professor, do your analyses show in any way whatever the effect of the sewage and sewage matter coming from Chicago down the Illinois River, caused by the opening of the drainage canal January 17, 1900?

5689 A. They do not in my opinion.

Q. So far as the assumption of the black sewage, muddy condition of the Illinois River water throughout its length and the various points along it, and the same condition, including Grafton and the Mississippi River between Grafton and the chain of rocks is concerned, I would state as my opinion that such assumption is altogether beyond the fact, that no such condition was to my knowledge observed along the course of the Illinois River, nor at Grafton, nor the Mississippi River between Grafton and the chain of rocks, but that, on the other hand, the result of my analyses, particularly those having to do with the appearance and the odor of the water, indicate that no such condition maintained or held except that in the upper
5692 stretch of the Desplaines River in the vicinity of Joliet, etc.

The conditions prevailing in the Mississippi River between Grafton and the chain of rocks, after the mixing of the waters of the Illinois with the waters of the Mississippi and the waters of the Missouri render it highly improbable that any considerable proportion of such pathogenic germs as may be contained in the waters of

the Illinois River at Grafton, that is, if we grant the assumption of the question, passes down the Mississippi to the point below St.
5697 Louis and is taken into the intake of the St. Louis waterworks.
5697 In my opinion, septic action takes place in the drainage canal. Explanation as to why any unusual appearance of black sewage muddiness occurred in the waters of the Illinois River after
5702 the drainage canal was opened on January 17, 1900.

5711 THOMAS J. BURRILL.

Professor of the Illinois State University for the advancement of science and president of the American Microscopical Society and member of the Western Naturalist Society; Ph. D. from the
5713 Chicago University and W. L. D. from the Northwestern University.

Beginning with May, 1899, I made a series of examinations from selected points on the course of the Illinois River, and this we continued until October, 1900, and then in 1901 a series was made extending from October to December, inclusive. These were for the most part weekly collections from the stations arranged for by Professor Palmer and Professor Jordan. There were two samples in each collection and in the whole for the two years first named there were 2,800 of these samples. The number of the entire cal-
5716 culations made for these samples amounted to about 7,000.
Table F. Streams' Examinations. Monthly averages of Colony
5724 County. Report of T. J. Burrill, University of Illinois.

Q. Will you please consider briefly the tables to which you have testified which contain the colony counts as indicated by you and point out the difference which exists in the bacterial contents of these waters in the different portions of the streams.

A. The difference in colony counts for different portions of the stream is marked, and while there is considerable variation for each point, there is for all of our tests very striking agreements near its head at Bridgeport, amounting to several million in a cubic centimeter, and then a more or less gradual decrease to Peoria, and
5729 from Ottawa to Peoria this decreased number is exceedingly marked.

AVERAGE FOR THE FOUR TESTS AT BRIDGEPORT, 2,497,000. AT AVERYVILLE FOR THE SAME TIME, AN AVERAGE FOR THE FOUR TESTS, 1,640.

For the year 1900 the average of four tests at Bridgeport was 6,037,500; while at Averyville for the same time the average was

13,087. The colony count showed a great increase in the number of bacteria after the pollutions were received by the river from Peoria and Pekin. As an illustration of this, I will say that in 1899, on November 1st, there were found at Pekin 2,780,000 bacteria per cubic centimeter; on November 9th, 170,000; November 16th, 145,000; on November 24th, 95,000; with an average for the four tests of 797,500. For the same period at Beardstown, which is fifty-six miles further down the stream, the average for the four tests was 17,590 for the year 1900. At Pekin, the average was 295,875, while at Beardstown the average was 3,700. The averages in the last figures show respectively 45.71 times as many bacteria in the water at Pekin as

at Beardstown, though the distance is fifty-six miles and the
5730-5731 time required for the flow of the water twenty-four hours.

I wish to say that the showing is for 1900 less than for 1899 in the first part of the stream as here indicated and more for some

distance after Havana, less at Kampsville, and more again at
5731 Grafton, Alton and Mitchell.

Q. The counts which are indicated thereafter, beginning with Havana and ending with Mitchell, show what condition?

A. Here, again, it was indicated that the comparative number of bacteria found is very much less than at Wesley City and at Pekin, but upon the whole very similar to these found from Ottawa to Averyville. The largest number represented in this section of the plate, that is, from Havana to Mitchell included, was in the Missouri River at West Alton, in 1899. This showing is not far different in

this part of the plate otherwise than is mentioned between the
5741 two years.

Q. Professor, will you please explain the significance of the variations in the number of bacterial counts at the various places indicated in the series of tables which you have just explained, beginning with table 21 and ending with table 28?

A. These tables present in a graphical way the very great difference in the number of colonies of bacteria found on our test plates made from water taken at these different places. It will be seen that without exception these numbers are very large from the waters taken from the Illinois and Michigan canal at Lockport, from the sanitary canal at Lockport, from the Desplaines River at Joliet, throughout the time that the examination was made. At Morris, also, the plates show that the number was very large, yet a considerable decrease from those at the places just mentioned, in most cases, though in the showing for August, 1899, the number is nearly as large as we find it to be at any of the places. This indicates to me that the waters

through this course of the stream have in them great quantities of decomposable organic matter suitable for food for these organisms, and that the other conditions are such that the latter multiply enormously in these waters; but between Morris and Ottawa the indications are, from these plates, that a great change takes place; that the numbers of bacteria are greatly decreased. This decrease is out of all proportion to the increase of water received by the stream during this time; in other words, the amount of dilution that the stream has after passing Morris. This decrease in the number is maintained with some irregularity to Averyville, where the number found, on an average, equals that of ordinary river water, not especially subject to contamination. This seems to be true in every case, as shown by these plates for the condition of things in the Illinois River at Averyville.

Q. State whether the bacterial counts at Averyville indicate whether or not the effect of the depositing of the sewage of Chicago into the Desplaines and Illinois Rivers has already soon disappeared.

A. This showing seems to prove that the pollution of the water at Bridgeport, and subsequently near the head waters, has practically disappeared at Averyville.

Q. And what do they indicate further down at Grafton, so far as the additional contribution of pollution is concerned?

A. The plates, taken together, show very conclusively great pollution of the stream below Averyville, but that the organic matter is largely absent in the course of the stream after it reaches Havana, and especially so at the mouth of the Illinois at Grafton.

Q. What do these plates indicate as to the comparative condition of the waters of the Illinois River at Grafton, the Mississippi River above Grafton, and the Missouri River just above its mouth at the place called West Alton?

A. There is practically no difference, so far as shown by these plates, in the waters of the Illinois River before they enter the Mississippi River at Grafton and of the Mississippi River above the mouth of the Illinois River at this place. There is, however, a continuous exhibit of a greater number of bacteria in the waters of the Missouri River at West Alton than there are in either the Illinois River or the Mississippi River at Grafton.

Q. What conclusion do you draw from this difference?

A. I can only infer that the waters of the Missouri River at West Alton have in them greater contamination than have the waters of the Illinois River and the Mississippi River at Grafton. I do not think I have enough information of the special reasons for the condi-

tions as shown for the waters of the Missouri River at West Alton to be able to say why the pollution is greater there than in the Illinois and Mississippi at Grafton. I will say, however, that the records of temperature in these waters show that those of the Missouri are for the most part somewhat lower than are those for the Illinois and the Mississippi. This lower temperature probably has something to do with the lessened rate of decrease in these colder waters than in the warmer ones, for it must be understood that the waters which have a temperature favorable to the growth and multiplication of bacteria clear up sooner than those not so favorably conditioned.

I would like to express my opinion, that the greater part of this clearing up from the pollution of the water is directly due to the agency of the bacteria themselves, and this will explain why I say that the more favorable the condition for the growth and multiplication of the bacteria the quicker the pollution disappears.

Q. Will you explain what is the effect produced by these bacterial agencies?

A. The bacteria have, in general, as a source of food, organic matter. They in this respect have the same influence upon this organic matter as do animals, reducing the compounds from their higher or complicated states to less and less complex conditions, until finally the hydro-carbons are so reduced to water and carbon dioxide and the proteid matters to ammonia, or, still further, to nitrites and nitrates ultimately; in other words, the principal role of bacteria in this regard is exactly opposite to that of green vegetation—the latter are concerned in building up organic compounds from the simpler states, and the bacteria are reversing the process, and ultimately the result is that the operations of the green vegetation are exactly destroyed; and we start over again with the condition of the substances in
5750 which we had them at first.

Q. Where you cannot attribute the presence of a large number of micro-organisms in water to natural causes, what inference do you draw of the possibility or probability that such contamination comes from sewage?

A. Sewage is richer food for bacteria than any other that commonly escapes into our river water courses from the land or from the sources of the earth otherwise. There is rarely found such very large numbers of organisms in river waters except from sewage contamination and I mean by this when the numbers run into the millions per cubic centimeter.

Q. When, in the examination of water at different points in a river, you discover a material reduction in the number of micro-

organisms found in the water, what inference do you draw with reference to the sewage that may have been in the river?

A. I think I am entitled to infer that the matter suitable for food for these bacteria has disappeared and since, as has just been stated, sewage is the richest food commonly in such water, I
5752 may further infer that the sewage has disappeared.

Plates for coli determinations of water in the Illinois, Missis-
5754-5755 sippi and Missouri Rivers.

If now we compare all results obtained from the waters at the mouth of the Illinois River with those in a similar way from the Mississippi above the mouth of the Illinois and of the Missouri at West Alton, we shall have the following examples: In the Illinois River, 31 positive, 23 negatitve, and 1 questionable result. In the Mississippi River water, 35 positive, 20 negative, 1 questionable result. From the waters of the Missouri River, 36 positive, 7 negative and 7 questionable results. This indicates that the organism is most often present in the waters of the Missouri river, next in those of the Illinois at the mouth, and somewhat less frequently in those of the Mississippi, if we take into consideration the whole time of the
5756 investigation.

Q. Based upon your bacterial examinations of the waters of the Illinois River and its tributaries, and of the Mississippi River and Missouri River, to which you have referred and which are embraced in the tables and plates which have been submitted in evidence by you, what is your opinion as to the effect produced, if any, upon the waters of the Mississippi River below the mouth of the Illinois River by the opening of the Chicago drainage canal in
5758 January, 1900?

A. In my opinion the very decided reduction of the number of bacteria found in the course of the stream up to the time the waters reach Averyville, causing the waters at this place to assume the character of a normal river water, indicates that the contaminations from the sewage introduced into the stream from Chicago has disappeared at this point, and I cannot otherwise than conclude that the evidence now presented shows that the water at the mouth of the Illinois River at Grafton is practically free from any such contamination introduced at Chicago. I find, also, that the contamination as indicated in the water at the inlet tower at the chain of rocks has a larger proportion of its contamination from the water of the Missouri River rather than from the combined waters of the Illinois and the Mississippi at this point. I can say that the opening of the drainage canal has had no effect upon the waters of the Mississippi River one way or the other.

Q. Professor, did you make any bacterial examinations of the waters of the Illinois River, the Mississippi River and the
5759 Missouri River in the months of October, November and December, 1901?

A. I did.

This examination consisted in the number of bacteria, cubic centimeters, and the identification of the bacillus coli communis and the weekly samples taken from the Illinois River at Averyville, at Pekin, at Grafton, the Mississippi River above the Illinois at Grafton, chain of rocks, and the Missouri River at Fort Bellefontaine
5761-5769 incl. and the table of those results are found on pages 5761-5769, inclusive.

The average number of bacteria at Averyville and the percentage of positive tests for the bacillus coli communis is 6.2; Pekin, 76; Illinois River at Grafton, 10.7; Mississippi River above the mouth of the Illinois, 11.5; chain of rocks, near Illinois shore, 21.7; mid-stream 50; near the intake tower, 36.3; Missouri shore, 57.

General average at all these points and the positive tests for bacillus coli communis is 41.1; Missouri River at Fort Belle-
5770 fontaine, 57.1.

Q. Now, please state, Professor, what significance you attach to the colony count and the presence of the bacillus coli communis as they appear in the table which you put in evidence, and also a graphical illustration in the plate just put in evidence.

A. This series of investigations shows very closely just what was present in the series for 1899 and 1900, already presented, and gives clear evidence that the water from the stream of Averyville is comparatively pure, or at least free from great numbers of micro-organisms, and is quite commonly free from the bacillus coli communis. The percentages of total tests which were positive in this examination proved to be 6.2. If we compare this water with the water taken from the Pekin station we find a very great difference and it shows local contamination. Since there is an average of 299,000 bacteria to the cubic centimeter and 7.6 per cent. of positive tests for the bacillus coli communis, this pollution at Pekin seems to have disappeared at the mouth of the Illinois River at Grafton, since the average number of colonists is 8,441 and the percentage of positive tests for bacillus coli communi is 10.7. If we compare the results from the waters of the Illinois River near its mouth with that of the Mississippi River at the mouth of the Illinois, we find the result in regard to the number of colony counts slightly in favor of the Mississippi River, as was found in the previous case, the average here being

5,407. The difference between 5,407 and 8,441 may or may not show a constant condition of facts, as the difference is too small for this purpose, but the tests in regard to these two waters made for the determination of bacillus coli communis favors somewhat the Illinois River water as against the Mississippi River water, since the percentage in the former is 10 per cent. and in the latter 1.5 per cent. At the chain of rocks, where four samples were each time taken across the stream, the indications are that the pollution increases from the Illinois shore to the Missouri shore, as this series of counts show, namely: For the Illinois shore, 52,177; for the mid-stream, 43,185; for the intake tower, 127,862, and for the Missouri shore, 32,845. This latter is the only count which does not support the statement just made.

5773 Comparing now these last results with those obtained from the waters of the Missouri River at Bellefontaine, or, as sometimes called, West Alton, the indications are that this latter stream is considerably more contaminated, since the average number of bacteria per cubic centimeter is 127,353, and the percentage of positive tests for bacillus coli communis is 57.1. This means, so far as this evidence can be taken to mean anything, that the waters at the intake tower are largely derived from the waters of the Missouri River, and to present this a little more clearly the results of the examinations of the waters of the Missouri at Bellefontaine and of those at the intake tower may be placed together. From the former, that is, the Missouri, the average number of bacilli per cubic centimeter is 127,353; at the intake tower the average is 127,862; the percentage of positive tests for bacilli coli communis from the Missouri River is 57.1 and from the intake tower is 36.3 per cent.

Q. What significance do you attach in running river water to the presence of bacillus coli communis?

A. The presence of this organism means to me more than anything else that the water is contaminated with sewage and that this shows its bad quality for drinking purposes. I will say that since bacillus coli communis and bacillus typhosus are mainly derived, so far as they are found at all in water, from the same source, that the very common presence of the former may be held to give some indication, though by no means a positive proof, of the presence of the water.

Q. Professor, now, day before yesterday, in your testimony in this case, you gave it as your opinion that the sewage from the City of Chicago had not produced any effect one way or the other in the waters of the Mississippi River, covering the months of October, November and December, 1901. Please state whether you still enter-

tain that opinion, after taking into consideration the tables which you have given in evidence this morning.

A. I don't think there is anything shown by these latter ex-
5774 aminations to warrant any change in that opinion.

CROSS-EXAMINATION,

5775 By Mr. Jeffries.

Q. Now, aside from the bacillus, what other disease produc-ing bacteria have you studied?

A. The bacillus tuberculosis, and upon this I may state that as soon as the discovery of this organism was made, I devoted very con-siderable attention to it, and as one result found a possibility of de-
tecting the organism through a special stain that has been
5778 pretty widely known.

I think the preponderance of opinion would be that pathogenic bacteria in the open running stream have less advantage than
5781 they commonly have in the bacterial test.

Q. Assuming that water has been infected with the typhoid bacillus at a given point, is it within the science of bacteriology to determine the exact point in the river where the water would not be infected by the typhoid bacillus so deposited?

A. If sufficient attention is given to the word "exactness" in
5784 the question, I will say it is impossible to so determine.

Q. Decrease in quantities of saprophytes means increasing
5788 opportunity for the longevity of typhoid in water, does it not?

A. That is possibly true, but the decreasing number of sapro-phytes is altogether a different matter from the small number of saprophytes originally present. In this latter case there is no doubt but that the bacillus typhosus, other things being equal, has a better chance for survival.

RE-DIRECT EXAMINATION,

By Mr. Todd.

MR. TODD: Have you made any observations or experiments in regard to the life of the bacillus prodigiosus in water, and, if so, please state the results of those observations and your opinion as to the longevity of that bacillus in water?

A. I have made such examinations frequently. This bacillus is well known to all bacteriologists, and is made common use of in bac-teriological laboratories for various purposes. In my own work, it

has been frequently used in connection with other organisms in various kinds of water, contaminated and otherwise, and the general result has been that this organism soon dies out in any kind of water.

I happen to have the exact results of an experiment made this last summer, and found that when the bacillus prodigiosus was placed in water, entirely sterilized and free from other organisms and kept at about room temperature, though the room temperature varied at that time between twenty and twenty-five degrees Centigrade, the organism did not last over four days in a living condition. When put in with various other organisms, some of which could live continuously in water, it was found that in several instances a few of the organisms were found after a period of five days, but in no other case were there any found living up to that length of time.

I think I am entitled to the opinion that under any ordinary circumstances bacillus prodigiosus will not live in ordinary tap water or in common river water or in sewage polluted water more
5792 than five days.

RE-CROSS EXAMINATION.

By Mr. Jeffries.

Q. Now, I will ask you if it is not a fact that where large bacterial counts are obtained the colony may be present and yet be masked or overgrown by the other bacteria, so that it cannot be detected?

A. Not to any very considerable extent. Bacillus coli communis, by the methods in use, has so even and distinct characteristics that it can be pretty certainly found, no matter what else is
5793 present.

PROF. E. O. JORDAN,

Professor at the University of Chicago for eleven years; graduated from the Massachusetts Institute of Technology in 1888; studied at the College of Physicians and Surgeons at New York. Was in the employ of the Massachusetts State Board of Health in connection with the work being done at the Lawrence experiment station. Did graduate work in Clark University and took the Doctor of Philosophy degree there in 1892.

Have taught public hygiene at the University of Chicago for several years. Have had to deal with the classis epidemics in this country and abroad, and have studied also several epidemics at first hand.

Was at Lowell with Professor Sedgwick investigating the typhoid epidemic. Have visited Stamford, Connecticut, in connection
5805-5806 with the milk epidemic.

More recently visited Ithaca and am familiar with the literature of the classis epidemics and have used the same in the instruction of my classes. In connection with my work on public hygiene and epidemiology, the subject called sanitary science has necessarily been considered. I have given special attention to what is known as bacterial sanitary science, including epidemiology and water chemistry. I have made analyses of the waters of the Illinois and Michigan canal for the Sanitary District of Chicago, drainage canal, of the Illinois River, of the Desplaines River, of the Kankakee River, Fox River, Big Vermillion River, Sangamon River, Mississippi and Missouri Rivers and of Lake Michigan. These examinations covered three periods of time, one extending from April, 1899, to the end of the year, the second period extending from the 1st of January, 1900, to the end of June, 1900, and the third period from October,
5807 1901, to the first of January, 1902.

Names of places where the samples of 1899 and 1900 were
5808 taken.

Q. How often were these samples taken during these two periods.

A. At approximately weekly intervals.

Q. At what point was the third series of examinations made?

A. This series, as I understand it, was taken by agreement with the authorities of the State of Missouri at certain designated points. Those points were at Peoria, from a short distance above and below the city, at Grafton at the mouth of the Illinois River, samples being taken from both the Illinois and the Mississippi at this point, and at the chain of rocks, the source of the water supply of St. Louis, where samples were taken across the stream as in the preceding examination. Examinations were also made from the Missouri River at Fort Bellefontaine. The analyses were made in laboratories which were
5809 established under my direction at Peoria, at Grafton and at St. Louis.

The points for the first two periods of the investigations at which samples of water were taken were agreed upon by a conference between Professor Palmer, Dr. Gehrmann, Dr. Reynolds, Mr. Randolph, Dr. Riley and myself in the office of the health commissioner at Chicago. * * * In consequence of this conference Professor Palmer and I were appointed to visit the places indicated
5810 and to select points and water takers.

The instructions given water takers, with a description of the
5811 outfit for taking the same.

Q. What was the general character of the analyses made of these samples?

A. These samples of water were examined physically, chem-
5813 ically and bacterially.

Q. In the bacterial analyses, what ascertainment was sought to be accomplished by you?

A. In the routine work the number of bacteria capable of forming colonies upon a nutrient agar plate was the principal determination. Examinations were also made to determine the relative abundance of colon bacilli.

The methods employed in collecting, sending and making the
5814 bacterial analyses for the year 1899 and 1900.

Q. In the chemical analyses of these waters, for what constituents were these analyses made?

A. Residue on evaporation, chlorine, oxygen consumed, nitrogen as free ammonia, as albuminoid ammonia, nitrogen as ni-
5815 trites and nitrates.

Methods pursued in the making of these different ascertain-
5815 ments.

5817 TABLES OF ANALYSES FROM MAY, 1899, TO DECEMBER, 1899.

5818 Table No. 81.

This table shows the results of analytical determinations upon the water of the Illinois and Michigan canal at Bridgeport * * * and shows that the water on the Illinois and Michigan canal was on these days simply sewage, varying in degrees of concentration
5819 and staleness.

Table 82.

Table 82 shows analyses made from the water obtained from the Illinois and Michigan canal at Lockport, a distance of some twenty-nine miles from Bridgeport. The significant constituents of the water show that but little change has taken place, except that it is further advanced in decomposition.

5822 Table 83.

Table 83 contained the detailed analyses of samples of water from the Desplaines River at Lockport, Illinois, obtained on different days from May 5th to December 26, 1899. The amount of the several significant constituents of this water indicates a water more or less polluted. The Desplaines River in fact receives sewage from

several of the suburbs of Chicago. The points selected from which samples were taken was above the mouth of the present drainage canal. The Desplaines River receives sewage from the suburbs of Chicago, Riverside, and other places that directly empty into it.

Q. From Table 83, being the analyses of the Desplaines River, what is your opinion as to whether the Desplaines River was a potable drinking water at that time?

A. From the analyses of this water, as well as the known facts regarding the entrance of sewage into the Desplaines River, I
5823 should not regard this water as being potable at this time.

Table 84.

Samples for this table were obtained from the Desplaines River north of Jackson street at Joliet, Illinois. From the chemical and bacterial constituents of this water it is evident that the mingling of the waters of the Desplaines with the waters of the Illinois and Michigan canal have resulted in little alteration of the composition of the canal water. The Desplaines River at this point must be re-
5826 garded as a stream charged with sewage.

Table 85.

Table 85 embodies the analyses of samples of water taken from the Desplaines River below the town of Joliet.

5828 Table 86.

Table 86 contains analyses of samples of water taken from the Illinois River at Morris, Illinois, between May 29th and December 26, 1899. About nine miles above Morris the waters of the Kankakee mingle with the waters of the Desplaines River, forming by their junction the Illinois River proper. The water of the Illinois River at Morris, therefore, shows the influence of dilution of the highly polluted Desplaines River with the purer waters of the Kankakee, although the comingling is not complete at this point. Some change in the composition of the water appears also to have taken
5829 place during its passage from Bridgeport to Morris.

5830 Table 87.

5832 Table 88.

Table 88 includes the analyses of water from the Fox River, near its mouth at Ottawa, Illinois, for this period. Sewage from several towns enters the Fox River, the principal towns being Elgin, with a population of about 22,000, and Aurora, with a population of about 26,000.

Aurora is about four miles above the mouth of the Fox River and Elgin is about fifty-five miles. The composition of the water is

what might be expected from its origin. It is a river water,
5833 receiving some sewage.

Table 89.

Table No. 89 contains the results of analyses of water from the Illinois River at Ottawa, Illinois, for this period. In the flow from Morris to Ottawa a very considerable change takes place in the composition of the water. This is principally due to more thorough mixing, but in a large part due to changes in the constituents of the water. The albuminoid ammonia and free ammonia, the oxygen consumed, the number of bacteria, are all lower than at Morris, indicating that a really considerable purification of the water has
5835 taken place during its passage from Morris to Ottawa.

Table 90.

Table 90 includes the analyses of water from the tributaries of the Illinois, the Big Vermillion River entering the Illinois above La Salle; the sewage of Streator and Pontiac enter the Big Vermillion. The determination for chlorine and residue on evaporation were influenced by the operation of a cement factory a short distance above the point of collection. This affords an explanation for the large amount of residue on evaporation and for the high chlorines in Sep-
5837 tember, October and November of this year.

Table 91.

Table 91 contains the analyses of the samples of water from the Illinois and Michigan canal at La Salle for this period. The large amount of free ammonia and albuminoid ammonia and the large number of bacteria show considerable pollution is present at
5839 this point.

Table 92.

Table 92 contains the analyses of samples from the Illinois River at La Salle. The various determinations show that considerable purification has taken place in the Illinois River during the flow
5841 from Ottawa to this point, a distance of twenty-two miles.

Table 93.

Table 93 contains the analyses of water from the Illinois River at Henry, Illinois. At La Salle the sewage and drainage of La Salle and Peru, with a combined population of about 17,000, enters the Illinois and Michigan canal, which discharges into the river and into the river itself.

Little additional impurity enters the river between La Salle
5843 and Henry, and little dilution enters.

Table 94.

Table 94 contains the analyses of samples of water from the

Illinois River at Averyville, Illinois, the samples being taken on various days between May 30th and December 26, 1899. Between Henry and Averyville there is practically no addition of impurity and little dilution, so that the changes occurring in this flow of thirty-six miles are due to oxidation and other processes. The point where the samples were taken is at the place known as the Narrows, near the Peoria waterworks, above the City of Peoria, and before any pollution from the city enters the river. The large amount of nitrogen in the form of nitrates at this point shows that a very considerable amount of oxidation of the organic matter has taken place. The small number of bacteria shows that the stream which was originally laden with the bacteria of the Chicago sewage derived from the Illinois and Michigan canal has practically freed itself from this bacteria in this flow of about 160 miles.

5845
5846 Table 95.

This table contains analyses of samples of water taken from the Illinois River a short distance below Peoria, near the place known as Wesley City. A large part of the sewage of Peoria, with a population of about 60,000, enters the Illinois River between Averyville and Wesley City. In addition to the house sewage, the discharges from extensive stock yards, the slop from distilleries and other refuse enter the river about this point of collection. The large number of bacteria in the water indicates the organic character of a large part of this pollution and shows the extent as well as the nature of the defilement.

5847

Table 96.

Table 96 contains analyses of samples of water taken from the Illinois River at Pekin. The mixing of the Peoria sewage and refuse with the river water has become more clearly complete by the time this point is reached, and in addition to the sewage of Pekin, a city with a population, I believe, of about 8,000, has entered that river, together with considerable distillery refuse. The sample was taken far enough below Pekin to get the effect of all this pollution, so far as practicable to show the mixing of the pollution, although here, as at Wesley City, the amount of pollution shown by the water in the middle of the stream was not the same at all times.

5849
5850 Table 97.

Table 97 contains analyses of samples of water from the Illinois River at Havana. A considerable decrease of purification takes place between Pekin and Havana, as shown by the different determinations in this table.

5851

Table 98.

Table 98 contains analyses of samples of water taken from the Sangamon River at Chandlerville, Illinois.

Chandlerville is about twenty miles above the mouth. A very considerable amount of sewage enters the Sangamon River and its tributaries from Springfield, with a population of about 35,000; from Bloomington, with a population of about 25,000, and from Decatur, with a population of about 20,000. This very considerable amount of pollution is not particularly manifest in any of the determinations in this particular table, but it comes out with considerable clearness in the determinations which were made for the relative abundance of colon bacilli as are shown in tables that will be presented later.

5853

5854 Table 99.

Table 99 contains analyses of samples of water from the Illinois River at Beardstown; between Havana and Beardstown the Sangamon River enters, but otherwise little additional impurity is added to the river.

5855

5856 Table 100.

Table 100 contains analyses of samples of water taken from the Illinois River at Kampsville. Between Beardstown and Kampsville only a very small amount of polluting material enters the Illinois River. In fact, from Beardstown to the mouth of the river, at Grafton, the polluting matters entering the river are relatively insignificant. Some dilution, however, occurs from small tributary streams. The small number of bacteria found on many occasions from the Illinois River at Kampsville, together with the amount of nitrates in the water, shows that the river at this point has practically regained the condition that it possessed at Averyville, above Peoria.

5857

5858 Table 101.

Table 101 contains the analyses for Grafton. These samples were taken at a point in the Illinois River, where no mixing with Mississippi River water was possible. The condition of the Illinois River at this point compares very favorably, chemically and bacterially, with the water of the Illinois River at Averyville and with the various tributary streams entering the Illinois.

5859

5860 Table 102.

Table 102 contains the analyses of samples of water taken from the Mississippi at Grafton. The collections were made at a point in the Mississippi River, where no mixing of water with the Illinois River was possible. From a sanitary standpoint the water of the Mississippi River above Grafton does not differ materially, so

far as can be determined by chemical and bacterial examina-
5861 tions, from the water of the Illinois River at its mouth.
5862-5866 Tables 103-4-5-6 and 107.

These tables contain results of analyses of samples of water taken from the Mississippi River above Alton, about twenty miles below the mouth of the Illinois River. The samples were taken at approximately equi-distant points across the river, with a view to determining, so far as practicable, the extent of the mingling of the waters of the Illinois and Mississippi Rivers at this point. The degree of the co-mingling of the waters of the Illinois and Mississippi at this point is approximately shown by the chlorine determinations. The higher chlorine on the east bank shows that a portion of the Illinois River water still hugs the Illinois shore, and that the water west of mid-stream to the right bank was largely, if not altogether,
5867 Mississippi River water.
5868 Table 112.

Table 112 contains the analyses of samples of water taken from the Missouri River at Fort Bellefontaine. Owing to the difficulties in making arrangements for the collection of samples, the analyses of water from this source were begun later than in the other case, so that the average of these determinations is not strictly comparable with the averages of other determinations, covering a
5869 different period.
5870-5873 inc. Tables 108-9-10-11.

These tables contain analyses of samples of water taken in cross-section from the Mississippi River at the chain of rocks, opposite the pumping station of the St. Louis waterworks. Between Alton and the chain of rocks the Missouri River enters the Mississippi River, about six miles above the point of collection. The Missouri River, like the Illinois River, has a high chlorine content and contains, as a rule, more bacteria per cubic centimeter than the waters of
5874 either the Mississippi or Illinois.
5881 Table 118.

Table 118 contains the analyses of samples of water drawn from the tap in the City of St. Louis, Missouri. The diminished amounts of suspended matter and the smaller number of bacteria in the tap water bear witness to some of the changes affected in the Mississippi River water through the settling basins.

The foregoing tables are the chemical analyses for the period prior to the opening of the Chicago drainage canal. The canal was not filled until the first of January, 1900, and the water did not pass out from the canal into the Illinois valley until the 17th day of January, 1900.

SECOND PERIOD OF ANALYSES AND THE TABLES WHICH COVER THE PERIOD FROM THE FIRST OF JANUARY TO THE END OF JUNE, 1900.

5882

5883 Table 119.

Table 119 contains the analyses of samples of water taken from the Chicago drainage canal at Kedzie avenue, between April 30th and January 25, 1900. As compared with the character of the water of the Chicago River, pumped into the Illinois and Michigan canal at Bridgeport during the period covered by the analytical work of 1899, these analyses indicate a water proportionately much less impure and much less heavily loaded with organic mat-

5884 ter.

5885 Table 120.

Table 120 contains analyses of samples of water taken from the Illinois and Michigan canal at Bridgeport. From January 2 to April 23, 1900. Some effect of the dilution of the contents of the Chicago River is shown by the various determinations in this table, the water of the Illinois and Michigan canal being during this period less highly charged with putrescribile organic matter than was the case before the opening of the drainage canal, with the consequent influx of purer water from Lake Michigan. At the same time the proximity of the pumping station at Bridgeport to the South Branch of the Chicago River, which is a practically dead end, allowed

5886 at times much organic matter and many bacteria to enter the canal.

5887 Table 121.

Table 121 contains the analyses of water taken from the Illinois and Michigan canal at Lockport from January 2 to June 25, 1900. The change in flowing from Bridgeport to Lockport

5888 during this period is, as in the year 1899, not a marked one.

5889 Table 122.

Table 122 contains analyses of samples of water taken from the Desplaines River at Lockport between January 2 and June 25, 1900.

Table 123.

Table 123 contains analyses of samples of water taken from the Chicago drainage canal at the bear trap dam at Lockport be-

5892 tween April 16 and June 25, 1900.

5893 Table 124.

Table 124 contains analyses of samples of water taken from

the Desplaines River north of Jackson street at Joliet between
5894 June 2 and June 25, 1900.
5895 Table 125.

Table 125 contains analyses of samples of water taken from the Desplaines River at Jefferson street, Joliet, between March 5 and June 25, 1900.

5896 Table 126.

Table 126 contains analyses of samples of water taken from the Kankakee River at Wilmington from January 22 to June 23, 1900. One of the chief differences between the analyses of the Kankakee River for 1899 and 1900 appears in the number of bacteria per cubic centimeter, the number being higher through the winter and early spring months of 1899.

5898 Table 127.

5899 Table 127 contains analyses of the samples of water taken from the Illinois River at Morris between January 5 and June 26, 1900. During the month of January the conditions were not dissimilar to those prevalent during 1899, but the analyses for subsequent dates show in several ways the effect of the dilution of the Chicago sewage in the Chicago drainage canal. The smaller amount of chlorine particularly is evidence of this increased dilution, and on several occasions, notably in the month of May, the number of bacteria in the Illinois River at this point was lower to a striking degree
5900 than at any time in the preceding period.

Table 128.

Table 128 contains the analyses of the samples of water from the Fox River at Ottawa between January 4 and June 25, 1900.

During the early part of this period the number of bacteria was much higher than in the period of 1899 and much higher than for the latter part of April and for May and June, 1900. This is a phenomenon of common occurrence in other waters, and so far as I am aware no adequate explanation for this occurrence has been ad-
5902 duced.

Table 129.

Table 129 contains analyses of samples of water from the Illinois River at Ottawa for the same period. The various determinations, chemical and bacterial, especially those showing the amount of albuminoid ammonia and free ammonia and nitrates and the number of bacteria per cubic centimeter, indicate that a considerable change in the direction of purification has taken place between Morris and Ottawa as in 1899.

Table 130.

Table 130 contains analyses of the samples of water from the Big Vermilion at La Salle for the same period. The number of bacteria during this period is on the whole higher than during the period for 1899. The amount of free ammonia for this period is much higher than in the latter part of the period.

5906 Table 131.

Table 131 contains analyses of the samples of water from the Illinois River at La Salle for the same period. During the month of January, February and March the number of bacteria is as in the other river waters that have been considered much higher than during 1899. The amount of free ammonia is likewise much higher during the first part of this period than during the latter portion.

5908 Table 132.

5909 Table 132 contains analyses of samples of water from the Illinois and Michigan canal at La Salle for the same period.

5910 Table 133.

5911 Table 133 contains analyses of samples of water from the Illinois River at Henry for the same period. Here again is shown the increase in the number of bacteria in the river water during the late winter and early spring. This has already been shown to be a common phenomenon and occurs in the tributaries of the Illinois as well as the Illinois itself. The diminished chlorine in the latter part of this period shows the effect of the dilution due to the opening of the Chicago drainage canal.

5912 Table 134.

5913 Table 134 contains the analyses of samples of water in the Illinois River at Averyville for the same period. Both the effect of purification and dilution are shown in this table, especially during the latter part of the period when the effect of the condition of early spring has disappeared.

5914 Table 135.

Table 135 contains the analyses of samples of water in the Illinois River at Wesley City. The smaller number of bacteria during this period as compared with the early period shows that the pollution entering the Illinois River at Peoria has been crowded in part towards the western bank and does not make its presence so evident in midstream as was the case during 1899.

5916 Table 136.

5917 Table 136 contains the analyses of the samples of water taken from the Illinois River at Pekin during this period. The effect of pollution here in the midstream sample is more manifest

than in the samples from Wesley City, owing possibly to a more thorough mixing at this point.

5918 Table 137.

Table 137 contains the analyses of samples of water taken from the Illinois River at Havana for the same period. The purification in the river is shown by the number of nitrates and the number of bacteria as manifested here, as well as in the 1899 period.

5926

Table 138.

Table 138 contains the analyses of samples of water from the Sangamon River at Chandlersville. The usual decrease in the number of bacteria is manifest at this point as in the other tributaries of the Illinois and in the Illinois River itself.

5922 Table 139.

Table 139 contains the analyses of the samples of Illinois River water at Beardstown for the same period. Taking into consideration the greater dilution of the water at this point, the analytical data are not materially different from those covering the 1899 period.

5924 Table 140.

Table 140 contains the analyses of the samples of water taken from the Illinois River at Kampsville for the same period. The usual spring rise in the number of bacteria, the amount of free ammonia and albuminoid ammonia and so on is manifested here as elsewhere, but during the latter part of the period the conditions of the water both chemically and bacterially compare very favorably with that in the 1899 period. The number of bacteria averages less at Kampsville than at Averyville. The amount of free ammonia is on the whole lower. The albuminoid ammonia is very similar.

5926 Table 141.

5927 Table 141 contains analyses of samples from the Illinois River at Grafton. A very considerable degree of purification is shown chemically and in the latter part of the period bacterially also as compared with the collecting stations in the upper stretches of the river. The increased volume of water in the Illinois River, especially in the months of March and April, is reflected in the lower chlorine contents during this period.

5929 Table 142.

Table 142 contains analyses of samples of water taken from the Mississippi River at Grafton. The amount of albuminoid ammonia in the water of the Mississippi during this period is on the whole

somewhat higher than the amount of the Illinois River from the samples taken on similar dates.

5931-5935 Tables 143, 144, 145, 146 and 147.

These tables show the analyses of a series of five samples taken at approximately equidistant points across the Mississippi above Alton, Illinois; the points of collection were the same as during the 1899 period. The analyses show that in 1899 period there is a lack of complete commingling of the waters of the Illinois and Mississippi Rivers at this point; the water derived from the Illinois River clinging as before to the left bank of the Illinois shore, as is shown particularly by the chlorine and nitrate determinations.

5936 Table 152.

Table 152 contains the analyses of samples of water taken from the Missouri River at Fort Bellefontaine. The larger amount of suspended matter carried by the Mississippi River in high water periods is shown by these determinations, especially by the suspended residue on evaporation by the amount of oxygen consumed by suspended matter and by the amount of nitrogen present in the form of albuminoid ammonia in suspended matter. Throughout the

5938 greater part of this period also the number of bacteria in the Missouri River water was high.

5939-5942 Tables 148, 149, 150, 151.

These tables contain analyses of water taken from the Mississippi River opposite the pumping station of the St. Louis waterworks at the chain of rocks from the same point as those for 1899. The considerable amount of suspended matter, as is shown by the residue on evaporation, which was present in the water of the Mississippi River at the inlet tower and in midstream at this point, when compared with the smaller amount of suspended matter in the Mississippi River above the entrance of the Missouri, indicates that the major part of the water entering the St. Louis intake during the period covered by these analyses was derived from the Missouri River rather than from the Illinois.

5950 Table 158.

Table 158 contains the analyses of samples of water taken from the tap at St. Louis, Missouri. The larger amount of suspended matter in the water of the Missouri River during the latter part of this period is reflected in the increased residue on evaporation in suspended matter in the tap water, although the reduction in passage through settling basins is very great.

5951 Q. Professor, will you please explain what the different chemical constituents disclosed by the tables just introduced mean

and their sanitary significance as well as the physical and bacterial determinations, and their sanitary significance as applied to the streams under investigation?

A. The physical characters of the water have been roughly determined with reference to the amount of turbidity, amount of sediment, the color and odor.

Little or no sanitary importance can be attached to the turbidity, sediment and color in the cases under consideration.

As regards the odor of the water, it is found that, in general, waters containing a large amount of organic matter in the early states of decomposition possess an offensive odor readily perceived by the senses, while less impure waters or waters further advanced in the processes of oxidation possess little odor, or, it may be, none at all. It sometimes happens, however, that waters containing a large number of microscopic forms of life, chiefly algae and infusoria, yield odors that are more or less offensive, and that simulate the odors of decomposition. The death and distintegration of these microscopic forms may likewise be the cause of disagreeable smells. Offensive odors, then, may or may not be accompanied by dangerous sanitary qualities.

5951

Turning next to the various chemical determinations, we may first consider the residue on evaporation. This determination gives information as to the amount of solid substances remaining after the water in which it was dissolved or suspended has been completely evaporated. During the process of thorough drying certain substances, organic and mineral, are decomposed and driven off.

In general polluted waters contain a rather high residue on evaporation, but in certain cases the residue on evaporation may have reference simply to harmless mineral matters in suspension. In all cases a distinction was made between the dissolved residue on evaporation and the suspended residue on evaporation, the determinations being made both upon filtered and unfiltered samples, the difference between the two being taken as the weight of the residue on suspension.

The determinations of chlorine may next be considered. Chlorine is present in practically all natural waters in combination with sodium in the form of sodium chloride or common salt. Owing to the large amount of salt in urine and in various forms of household waste, it has been found that sewage contains an amount of chlorine in marked excess of that present in most natural and unpolluted ground and surface waters.

When the amount of chlorine normally present in the unpolluted

wells and springs of a given district is accurately known, it becomes possible to determine with a considerable degree of precision the amount of pollution existing in the various ground and surface waters of that region which have received a larger or smaller amount of drainage.

5952 The contents of water in sodium chloride is therefore under some conditions a fairly satisfactory gauge of the sanitary condition of that water. Owing to the permanence of the salt, however, the amount of chlorine in a polluted water does not afford conclusive indications as to whether the pollution is recent or remote. In following the passage of salt down stream in a polluted river the permanency of this substance renders it a valuable indication of the degree of dilution and mixing, but, on the other hand, does not afford a clew to the rapidity and extent with which processes of oxidation and bacterial purification are taking place.

The determinations known as oxygen consumed concerns especially the carbonaceous matter in the water.

The significance of this determination lies in its comparative rather than its absolute value, since the amount of oxygen consumed as determined by the quantity of permanganate solution consumed during heating is affected materially by the period of heating and by other factors. Exact uniformity of the analytical processes involved is therefore of great importance, and in order that the results in one and the same laboratory shall be strictly comparable throughout, it is necessary to maintain perfect uniformity of procedure. The changes taking place in carbonaceous matter in a water cannot be followed step by step, as is the case with the nitrogenous compounds, since the carbon di-oxide formed in decomposition processes either goes off or enters into combination with mineral elements.

The most significant organic compounds in a polluted water are those of nitrogenous character. These nitrogenous compounds are usually determined in four different states, as albuminoid ammonia or organic nitrogen, as free ammonia, as nitrites and as nitrates.

If we follow the history briefly of the waste nitrogenous compounds discharged from the animal body, it is as follows:

These compounds are at first relatively complex and are chemically highly organized bodies. When subjected to bacterial action free ammonia is liberated from these substances and enters into loose combination with certain of the elements present in the water or sewage. When a water into which such matters have been received a short time before is heated the ammonia is driven off in the steam

and can be collected and measured with a considerable degree of accuracy.

5953 This is the so-called free ammonia in the analytical tables.

The nitrogen in the more chemically complex substances, on the other hand, is for the most part not driven off by this process. This is the so-called albuminoid ammonia, the amount of which, however, can be determined by heating in an alkaline solution in the presence of permanganate destruction of the albumin or nitrogenous molecule taking place under these conditions. This process results in the liberation of ammonical compounds which can then be distilled over, collected and measured by the same method as used for the determination of the free ammonia.

In general it may be said that a fresh sewage contains a relatively large proportion of nitrogen in the form of albuminoid ammonia, while a stale sewage contains a smaller proportion of nitrogen in the form of albuminoid ammonia into free ammonia.

These early stages in the decomposition of organic matter are followed by oxidation processes which result in the conversion of the free ammonia of the water into nitrites, nitrites being less highly energized compounds than the ammonical compounds from which they have been derived. The reason for this oxidation process resides in the need of bacteria for food. Food being matter containing available potential energy, many kinds of bacteria are able to obtain this energy from the ammonium compounds.

Under favorable conditions the process of oxidation does not stop here, as certain bacteria are able to obtain the energy necessary for their development ever from compounds containing so little available potential energy as nitrites, and are able to carry on their vital processes with the aid of the energy derived from the oxidation of the nitrites, which, by virtue of this bacterial activity, are converted into mineral nitrates, the nitrogen then passing successively through the various stages of albuminoid ammonia, free ammonia, nitrites and nitrates. The oxidation of the free ammonia into nitrites and of the nitrites into nitrates is what is termed the process of nitrification. The importance of these facts from the sanitary side is due to the connection of these oxidation processes of purification.

5954 In general large amounts of albuminoid and free ammonia indicate the existence of products of decomposition, while the presence of a large amount of nitrate, together with little free and albuminoid ammonia and little nitrate, characterizes a water which may perhaps in the past have received a considerable quantity of polluting matter, but which after the lapse of time and thorough bac-

terial activity, has become relatively stable. It has been found empirically that waters in which these oxidation processes have taken place less commonly give rise to disease or are a source of danger than waters that have received recent pollution, as indicated by the relatively high amounts of free and albuminoid ammonia.

The number of bacteria in a water is usually determined by mixing an accurately measured quantity of the water with nutrient beef jelly and then pouring the mixture out into a sterilized glass dish. The theory underlying this procedure is that each germ originally present in the water, finding itself in a favorable nutrient medium, grows, multiplies and in a few hours or days has formed about itself a growth or colony large enough to be plainly visible to the naked eye.

Different kinds of bacteria form colonies that can be distinguished one from another by various physical characters. The kinds of bacteria in a water vary greatly in their sanitary significance, most being perfectly harmless saprophytic forms, which do not, so far as is known, have any injurious effect upon the human system, even when taken into the alimentary tract in large quantities. Others, the pathogenic or so-called pathogenic germs, are able when taken into the animal body, under suitable conditions, to produce poisonous substances which damage the organism.

The number of bacteria per cubic centimeter, as enumerated in the analytical tables 81 to 158, includes the colonies of all kinds developing upon the bacterial plates, no distinction being made between the harmless and injurious kinds.

By enumerating the number of colonies occurring on one of these plates of beef jelly or nutrient gelatin, some approximation can be arrived at regarding the number of germs originally present in the waters, although the absolute number of bacteria in a water is not always convincing evidence of the sanitary quality of water, since under certain laboratory conditions bacteria may be made to multiply in a pure water. At the same time experience has shown that in waters collected under natural conditions from springs, rivers, lakes and reservoirs the purer waters contain fewer bacteria, while those waters that are polluted with sewage or large quantities of organic matter contain numbers of bacteria much in excess of those found in purer waters. Under natural conditions it is in general true that as the food supply of bacteria diminishes the number of germs becomes fewer, while an influx of food material favors the longevity of certain bacteria and their further multiplication. Surface waters con-

5955

tain, as a rule, larger numbers of bacteria than ground waters which have been freed of a portion of their bacterial content by filtration through layers of sand or soil. It has been observed that the water of a sewage polluted river may contain large numbers of bacteria just below the source of the pollution, but that these numbers diminish with the passage of the water down stream.

3956 Q. What do the tables and table of averages read into the record by you show as to the purification of the waters of the Illinois River for the period of 1899, interpreting the sanitary significance of the different chemical and bacterial constituents which you have heretofore explained?

3960 A. From an examination and consideration of the tables of separate analyses and the tables of averages for this period, the period of 1899, it appears that the water in the Illinois and Michigan canal at Bridgeport and at Lockport, as well as the water the Desplaines River at Joliet and of the Illinois River at Morris, contained throughout this period a large amount of nitrogenous organic matter in the early stages of decomposition. It appears also from the large amount of chlorine present in these waters that the initial pollution of the Illinois River reached a considerable height during this period. The large number of bacteria present in these waters shows that the substances capable of serving as food for these organisms were present in great abundance.

The tables and averages also show that by the time the Illinois River reaches Ottawa, being somewhat diluted in the course by the purer water of the Kankakee, mingling with which is incomplete at Morris, a very great change has taken place in the composition of the river water, a change which is manifested especially by the diminution in the amount of albuminoid ammonia, by the increase in the amount of nitrites and nitrates and particularly by an enormous and significant diminution in the bacterial content.

The oxidation of the organic matter continues with the passage of the water down stream, and by the time the flow reaches Averyville the amount of free ammonia is greatly diminished as compared with the amount at Ottawa. The amount of albuminoid ammonia is diminished. The amount of nitrites is somewhat lower than it was at Ottawa. The amount of nitrates has greatly increased, while the bacteria which were present in such enormous numbers in the waters of the upper Illinois have now sunk to a point where they can be compared with the number present in ordinary surface waters in the United States, and with the number present in the tributaries of the Illinois during this period.

Below Averyville the Illinois River receives a large influx of polluting material from Peoria, with its stock yards and distilleries, which is evidenced by the increase in some of the significant constituents in the river water, notably in the free ammonia and the albuminoid ammonia and in the number of bacteria.

At Pekin some additional pollution is received, and the mingling of the Peoria sewage with the Illinois River water has become more perfect. From Pekin to the mouth of the river the purification follows a generally progressive course, until by the time the mouth of the river is reached at Grafton the amount of free and albuminoid ammonia, the oxygen consumed by the carbonaceous matter and the number of bacteria are again low, while the relatively large amount of nitrates bears witness to the practically complete oxidation of the enormous amount of organic matter with which the sewage was laden at Peoria, as well as that with which it originally set forth at Lockport.

5961 Q. For the period 1900?

A. The conditions in the Illinois River during the larger part of the period covered by these investigations are shown by analyses of samples collected at the same points and under the same conditions as in 1899, the whole series of analyses from May, 1899, to the end of June, 1900, forming one continuous period.

From April to June, 1900, analyses were made of the water from the Chicago drainage canal at Kedzie street and at Lockport. These analyses show that as compared with the conditions of the water in the Chicago River considerable dilution has taken place, as witnessed particularly by the chlorine determinations as well as by similar changes in the other constituents of the sewage.

A mingling of the waters coming from the Chicago drainage canal at Lockport and from the Illinois and Michigan canal at Lockport, with the waters of the Desplaines River, which is subsequently joined by the Kankakee, took place during this period. The first admixture of the waters of the drainage canal took place on the 17th of January, 1900, after the canal had been filled, and the gates finally opened.

Examination of the separate analyses of the samples of water from the Illinois River at Morris and also of the averages of these analyses shows that the water of the river at this point was charged with organic matter; that it contained a large amount of nitrogen in the form of albuminoid and of free ammonia; that the amount of oxygen consumed was high, and that the number of bacteria was still large.

The samples of water taken from the Illinois River at Ottawa during this same period showed that considerable purification took place between Morris and Ottawa, the amount of free ammonia and of albuminoid ammonia and of oxygen consumed being diminished, and the number of bacteria being little more than one-fourth the number in the Illinois River at Morris during this same period.

By the time Averyville is reached the process of purification had proceeded still further, both free and albuminoid ammonia being notably lower at Ottawa.

At this station also the amount of nitrate was high, showing that considerable nitrification had taken place in the flow from the drainage canal to this point. The number of bacteria was not half as great as in the Illinois River at Ottawa during this same period.

A further addition of polluting water took place at Peoria and Pekin, with the result that in the lower half of the river the process of purification had again to be completed. How complete this purification was may be seen from the determinations at Grafton for this period, the amount of free and albuminoid ammonia in the water and the amount of nitrates indicating that this purification followed a parallel course to the purification in the upper half of the river.

This second period, the conditions in which have been just described, has been arbitrarily separated from the first period, namely, that for the months of May to December, 1899, but the analyses show plainly that the essential course of events in the water of the Illinois River is the same, whether a period of two months or five months or fourteen months be considered.

In all cases the same phenomenon is noticed. The water at the outset, highly charged with putrescible organic matter and laden with sewage material, regains in the course of about 130 miles flow the condition usually existing in surface waters in this country.

The entrance for a second time into this stream of a large mass of polluting matter, an event that occurs at Peoria and Pekin, as heretofore pointed out, is followed by a second successful attempt on the part of the stream to purify itself of this added load.

The self-purification of the Illinois River during the period covered by this analysis, extending from May, 1899, to the end of June, 1900, is notable in character and extent, both at high water and at low water, both at low temperatures and at high temperatures, and shows convincingly that under the conditions prevailing in the Illinois valley during the period studied the self-purification of streams is not an interesting biological myth, but an actual and definite occur-

5965 rence.

Q. Professor, while these tables have been presented as covering two periods of investigation, as a matter of fact the investigation covers one period, does it not

A. It certainly does. There was practically no break in the analyses, as they were conducted in my laboratory from May, 1899, to the end of June, 1900, weekly analyses being made throughout this period, with a few exceptions.

Two periods during the course of this examination compared.

5965 Q. How does the chemical and bacterial condition of the Illinois River at Averyville, Kampsville and Grafton, for the period covered by this survey, compare with that of its tributaries for the same period?

A. So far as the chemical and bacterial determinations show the condition of the Illinois River at Averyville, Kampsville and Grafton differs in but slight and insignificant particulars from the waters of the tributary streams. * * * So that, considered from the point of view of a comparison of the chemical and bacterial analyses, the condition of the Illinois River at Averyville, Kampsville and Grafton compares favorably with the immediate tributaries of the Illinois.

5966-5967 Throughout the period covered by this investigation the waters of the Illinois River at Pekin were usually in a more highly polluted condition chemically and bacterially than the waters of the Illinois River at Averyville. The water of the Illinois River at Grafton is usually in a condition very similar to that obtained at Averyville.

Q. How far from Peoria is Kampsville?

A. About 124 miles.

Q. How far is Averyville from Lockport?

A. About 130 miles.

5968 Q. During this entire period do your chemical and bacterial examinations disclose the presence at Kampsville of the sewage from Chicago, whether from the Illinois and Michigan canal for the first part of this period or from the Chicago main drainage canal for the second?

A. They do not, so far as the number of bacteria in the water is concerned, nor do they so far as the various chemical determinations of albuminoid ammonia, oxygen consumed, nitrites and nitrates are concerned. The large amount of chlorine that enters the Desplaines River along with the Chicago sewage is, however, permanent, and not being liable to destruction by various influences, as is the

case with the nitrogenous organic matter and the bacteria that are added in the Chicago sewage, the chlorine manifests itself at Kampsville and Grafton and even beyond into the Mississippi River.

5969 The presence of chlorine in water of a river in the absence of other chemical ingredients would be absolutely devoid of sanitary significance. It would be possible for a stream in the condition that the Illinois River was in at Kampsville to be passed around the world several times in a closed conduit, consuming years or decades in the process, without altering materially the amount of chlorine in the water, although it is my judgment that, supposing the water was at the outset injurious to health, in the course of such a passage and in such a time it would become entirely free from any injurious qualities it might have originally possessed.

5969 Distances from Bridgeport in miles are as follows: Lockport, 29 miles; Joliet, 33 miles; Morris, 57 miles; Ottawa, 81 miles; La Salle, 95 miles; Henry, 123 miles; Averyville, 159 miles; Wesley City, 165 miles; Pekin, 175 miles; Havana, 199 miles; Beardstown, 231 miles; Kampsville, 288 miles; Grafton, 318 miles.

5981 Photograph of a schematic representation to illustrate the various stages in the decomposition and oxidation of nitrogenous

5982 organic matter.

Free ammonia at the mouth of the Illinois River, for example, may be derived from a decomposition of algae, while free ammonia at Lockport or Bridgeport may be derived from decomposition of waste substances leaving the human or animal body or discharged into the water in the course of various manufacturing operations. This diagram, I think, serves to illustrate some of these points and to show the complexity of the phenomena attending the decomposition of organic compounds, containing nitrogen, and the recomposition of this nitrogen into bodies of other living forms.

5984 Q. Did you make any hourly bacterial survey in the water of the Illinois River below Morris?

5985 A. Yes, sir.

Tables of hourly examinations.

Attention may be directed to the fact that between these collecting stations, a distance of three miles, traveled by the stream on this date in about six hours, a great bacterial diminution occurs. It should be noted that the decline in the number of bacteria occurs in almost equal degree throughout the whole breadth of the stream, being as great along the highly polluted right bank of the river as along the comparatively uncontaminated left bank.

5986 Series of observations carried out in November, 1899, upon a

larger stretch of the river. The distance between the regular
5987 collecting stations at Morris and Ottawa of about twenty-four miles.

Tables of these experiments.

During this flow of twenty-four miles, therefore, the Illinois River became nearly free from the great mass of sewage bacteria with which it was originally laden. In fact, the bacterial content of the Illinois River at Ottawa on this day was not greatly in excess of that of the local tributary streams.

Third series of similar observations was made between these same points on May 24-25-26, 1900.

5989-90 Tables of results for these experiments.

The bacilli coli communis, or the colon bacilli, is, as its name implies, a bacterium inhabiting in large numbers that proportion of the alimentary tract known as the colon. It is the bacillus commonly found in this situation. It is found in the intestinal discharges, not only from man, but from many other of the higher animals. It is found also in waters and soils contaminated with animal excreta. It is found sometimes in the dust of streets. It is sometimes, though rarely, found in the air, in pure water and in the deeper layers of soil it is found, if at all, in very small numbers. The colon bacillus is exceedingly similar to the typhoid bacillus in many of its mor-
5995 phological and biological characteristics.

5996 COLI CHARACTERISTICS.

The colon bacillus is in every respect more hardy than its near relative, the bacillus typhosus. In comparative tests that have been made on the relative viability of the bacillus coli and the bacillus typhosus, under certain conditions, the following facts have been demonstrated.*

5996-97 Q. What is the significance of the bacillus coli communis in sanitary water analyses?†

Q. Will you state the methods employed by you in the determination of the bacillus coli communis?‡

Table of analyses for coli determination upon samples of water
6008 collected between May, 1899, and June, 1900, at the same places selected for chemical analyses.

*Read the experiments.

†The answer to this question is comprehensive, covering the importance of the coli in sanitary water analyses and should be read in its entirety.

‡Read the answer to this question in full, as it is comprehensive 6005.

6009-35 Tables of coli determination at the various points from Chicago to St. Louis.

6036 Table of summaries.

This table summarizes the results obtained from the colon determinations made upon the water collected at the principal stations along the Illinois River. It shows that in the water of the Illinois and Michigan canal at Lockport the bacillus coli was present in .001 of a cubic centimeter of water on twenty-eight days of the thirty-two days on which examinations were made. It shows further that in the water of the Illinois River at Morris the colon bacillus was present in .01 of a cubic centimeter of water on twenty days out of thirty days on which examinations were made, while at Ottawa it was present in the same quantity of water on only six days out of twenty-two days on which examinations were made.

At Ottawa the colon bacillus was found in .1 of a cubic centimeter of water on nineteen days out of thirty-four days on which examinations were made, while at Averyville it was found in the same quantity of water on only five days out of twenty-seven days on which examinations were made.

The increased pollution of the water at Wesley City is shown by a larger number of colon bacilli, as indicated by the fact that the colon bacillus was found in 1 cc. of water from this point on thirteen days out of twenty-six days on which examinations were made, or more than three times as frequently as in the Illinois River at Averyville above Peoria.

At Grafton, at the mouth of the river, the colon bacillus was found in .1 of a cubic centimeter on thirteen days out of thirty-five days on which examinations were made.

These summaries show that the colon determinations coincide with the results of the routine chemical and bacterial examinations already referred to.

The process of oxidation of the organic matter, the death of the mass of sewage bacteria and the mortality among the specially significant group of colon organisms appear to run a closely parallel course, and the inference as to the purification of the stream drawn from the chemical analyses and from the count of bacterial colonies is further emphasized by the mortality shown to occur in this significant class of sewage bacilli.

6037 Table of summaries comparing the Illinois River at Averyville and Grafton with the tributaries and with the Mississippi and

6038 Missouri River. * * *

The last series of determinations show that on May 24, 25

and 26, 1900, the mixing of the Kankakee and Desplaines Rivers at Morris was more complete than on November 9, 10 and 11, 1899. They also show a smaller number of bacteria per cubic centimeter of the water at this time. A diminution in the number of bacteria, however, similar to that noted in the earlier series takes place during the flow from Morris to Ottawa, and there are fewer bacteria per cubic centimeter, as shown by the colony count at Ottawa during this period in 1900 than in November, 1899.

I see no escape from the conclusion that in this flow of approximately twenty-four miles the Illinois River, which at Morris contained a large number of bacteria, in all probability derived more or less directly from the sewers of Chicago, freed itself from this bacteria to a remarkable and impressive degree in a short distance, and in a relatively short space of time. The probable reason for the high mortality among bacteria in this particular stretch of the river

5991 will be discussed in another connection.

The samples for these experiments were taken from a rowboat. The floats and flourescein introduced into the water were followed down stream in the boat so that it was possible to determine very closely the passage of a given body of water from one point to another, the object of the experiment being to observe the changes in one and the same mass of water flowing from point to point.

5991 Q. What sanitary significance do you attach to the experiments conducted by you at Morris which have been testified to by you in evidence?

A. This observation upon the bacterial content of the Illinois River between Morris and Ottawa indicate, in my judgment, that a very large proportion of the bacteria entering the Desplaines River from the Illinois and Michigan canal and from the Chicago drainage canal do not survive to reach Ottawa. From a sanitary point of view this observation would seem to be of importance in that it renders less probable the passage of disease germs down the river as far as this point. Since this sewage bacteria disappear in such numbers, it is in my opinion fair to assume that the various non-spor forming pathogenic bacteria entering the Chicago sewage die out at least in the same proportion.

5993 BACILLUS COLI COMMUNIS.

Q. Did you make any determinations for the bacilli coli communis?

A. I have made several series, the first covering the period between May, 1899, and June, 1900. This was made from samples of

water collected from the points heretofore given where water
5994 was collected for chemical analyses.

Summing up these facts in the second division of this table, it is seen that samples of water taken on sixty-nine different days from the Illinois River at Averyville and at Grafton contained bacillus coli communis on thirty-nine days, while various tributaries of the Illinois River, samples from which were taken for sixty-nine days, contained colon bacilli on thirty-six days. Samples taken from the waters of the Missouri on sixty-six days contained colon bacilli on forty-four days. It appears, therefore, from these tables that if the opinion that I have expressed regarding the sanitary significance of the colon bacillus in water is correct the water of the Illinois River at Averyville and Grafton was not materially different from what it would have been if the tributaries of the Illinois, exclusive of the Desplaines River and its sewage contents, had alone fed the basis of this stream. The colon content of such a stream at Averyville and at Grafton would have been substantially what it is
6039 at present.

Q. What sanitary significance do you attach to the tables of colon determinations as presented in evidence by you, considering them as a whole?

A. As stated in my testimony of yesterday, my experience leads me to adopt the view that the relative abundance of the colon bacillus in water affords the most satisfactory single analytical indication that sanitary science at present possesses as to the sanitary quality of a natural water.

Basing my opinion upon this, I may say that I regard the relative abundance of colon bacilli in the water of the Illinois River at various points, and in the various tributary streams, as furnishing a highly important clew to the freshness of the pollution entering, and the amount of real purification undergone by each stream. Considered from this standpoint the water of the Illinois River at Averyville and at Grafton is no more impure than the water in the principal tributaries of the Illinois, and certainly no more impure or dangerous than the water of the Mississippi River at Grafton, or the Missouri River at West Alton. The successive and striking diminution in the number of colon bacilli at various points along the Illinois River from Lockport to Averyville is proof in my judgment of the occurrence of a process of genuine self-purification.

Q. What sanitary significance do you attach to your chemical, bacteriological and colon determinations heretofore introduced into evidence, as evidenced by the tables introduced for the period extending from May, 1899, to the end of June, 1900?

A. I regard these determinations as forming a connected and correlated whole, mutually sustaining one another, and all pointing, in my judgment, to but one interpretation. The oxidation of the organic matter that was introduced in enormous quantities at Lockport, the more or less complete destruction of the sewage bacteria also introduced at this point, and especially the high mortality among the colon bacteria occurring in the upper stretches of the river, all appear to me to indicate that infectious matters that might have been introduced into the sewage of Chicago and found their way into the drainage canal during this period from May, 1899, to the end of June, 1900, did not make their way down river so far as Averyville. So far as my interpretation of the results of the chemical analyses is concerned, I have no hesitation in expressing as my opinion that the water of the Illinois River at its mouth is no more liable to convey disease or to produce injurious consequences of any kind than the waters of the Mississippi River at this point or the water of the Missouri River at West Alton. In expressing this opinion I am taking into consideration all the knowledge that I have acquired by personal experience and all the information that I have obtained regarding the chemical and bacterial contents of these waters during
6040 the period under consideration.

Survey of the waters of the Illinois and Mississippi and Missouri Rivers in 1901 as per agreement between the State of Illinois and the State of Missouri. The establishment of laboratories
6041-6042 at Peoria, Grafton and St. Louis.

The work done during this period was wholly bacterial in character and grouped as follows:

A. The determination of the number of bacteria in the river water as shown by the ordinary colony count.

B. The number of germs of the colon group in the river water as shown in the river water as shown by the dextrose fermentation tube test.

C. Study of the species of bacteria isolated from the river water.

The first two determinations were carried out in the respective branch laboratories and it is certain that a decided gain in the accuracy of the results was attained in conducting this work at or near the points of collection upon freshly collected samples; instead of allowing, as in the previous work, a considerable intervals to elapse
6043 while samples were being transferred to a distant point.
6044 Methods employed for this work.
6046 Tables of determination at Averyville.

6049 Sanitary significance of the tables.
6051 Tables at Pekin.
6054 Tables of Grafton, Illinois River.
6059 Tables of Grafton, Mississippi River.
Tables, Mississippi River, chain of rocks, Illinois Shore. Mid-
6064-6076 stream. Intake tower, Mississippi shore.
6077 Tables, Missouri River, Bellefontaine.
6081 Table of averages.

Q. State what this table of averages shows and what conclusions you draw from it from a sanitary standpoint.

A. This table contains the averages of the colony counts made from the water of the Illinois River at Averyville, at Pekin and at Grafton; from the Mississippi River at Grafton, and in cross-section at the chain of rocks, and from the Missouri River at Fort Bellefontaine. The number of bacteria found at Averyville and at Grafton was not dissimilar. These averages were higher than the average for this period in the Mississippi River. The usual winter increase which occurs in river waters took place this year in the Illinois River before making its appearance in the Mississippi. Up to the middle of December, 1901, the two waters were very similar as regards their bacterial contents. Throughout the whole of the period studied, the average number of bacteria, as shown by the colony count in the water of the Missouri River at West Alton, was several times as great as the water in either the Illinois River at its mouth or the Mississippi River above Grafton. The number of bacteria in the Illinois River at Pekin, as shown by these averages, was greatly in excess of that found at any other of the collecting stations, as in my opinion naturally follows from the entrance of the sewage and refuse of
6081 Peoria into the river above this joint.
6082 Table of cross-section of the Mississippi River, chain of rocks.

Q. Will you state what the table shows and the sanitary significance?

A. This table contains the results of the bacterial counts made upon samples of water taken from the Mississippi River at the chain of rocks. The averages are arranged in their proper relation, namely, the Illinois shore, mid-stream, intake tower and Missouri shore, the count for the Missouri River being contained in the right-hand column. These figures show that during the period covered by this investigation the number of bacteria in the water of the Mississippi River at this point was much lower on the Illinois shore than on the Missouri shore. It shows, moreover, that the water of the intake tower during this period partook of the character bacterially of the

water of the Missouri River and of the Mississippi River on the Missouri shore. In other words, during these three months of 1901, judging from the bacterial contents of the Missouri River and of the Mississippi River at this point, little, if any, water from the Illinois River entered the intake tower of the St. Louis waterworks. It is evident also from the bacterial count that if any water from the Illinois shore did pass into the water intake, it improved the condition of this water, so far as reducing the number of bacteria per cubic cen-

6084 timeter was concerned.

6084-6085-6086 Photograph of bacterial results.

Q. What purpose did you have in view to be subserved in making determinations for the bacillus coli communis?

A. The relative abundance of the colon bacillus in water I consider as affording the most satisfactory indication of the sanitary quality of such water. In my opinion this is the judgment of most sanitary experts at the present time. In a paper entitled, "The Significance of Bacteriological Methods in Sanitary Water Analysis," published from the Biological Laboratories of the Massachusetts Institute of Technology, by C. E. Winslow and C. P. Nibecker, and printed in the Technology Quarterly, Volume 16, No. 3, September, 1903, appears the following statement:

"Colon bacilli are either wanting in good waters or are so rare as not to be found in the examination of samples of one cubic centimeter, they are found in a majority of one cubic centimeter of water so polluted as to be dangerous for drinking; between these two extremes their numbers vary with the amount of pollution. Klein and Houston in England, Jordan and Winslow and Hunnewell in America, and very recently Petruschky and Pusch in Germany, have exhaustively studied the distribution of the colon bacillus with uniform results, and that the absence of this organism demonstrates the harmlessness of a water as far as bacteriology can prove it, no one would probably hesitate to acknowledge; and that when present its numbers from a trustworthy measure of its sanitary condition, the observers above quoted have proved beyond reasonable cavil."

This statement represents my own judgment in the matter as well as what is the prevailing opinion among sanitary experts generally and it is for this reason that in my studies into bacteriological conditions existing in the waters above mentioned, I have paid par-

ticular attention to the presence and relative abundance of the

6093-6094 colon bacillus.

Methods for the determination of coli bacilli in the examina-

6095 tions made in 1901.

Coli tables, Illinois River, Averyville, Pekin, Grafton; Missis-

sippi River, Grafton; Missouri River, Bellefontaine; Mississippi
6097-6116 River, chain of rocks.

Table A of summaries, showing presence of bacteria of the
6118 colon group from the collecting stations in 1901.

Table of summaries, showing presence of and percentage of
6120 bacteria of the colon group.

Q. What sanitary significance do you attach to your tables of colon determinations, considered as a whole?

A. In my opinion the fate of the colon bacillus in running water furnishes a very satisfactory indication as to the degree and rate of self-purification in such water.

The fact that the colon bacillus is present in but 43 per cent. of the .1 c. c. examinations from the Illinois River at Averyville, while it is present in 100 per cent of the .1 c. c. samples taken from the Illinois River at Pekin and in only 13 per cent of the .1 c. c. sample taken from the Illinois River at Grafton, shews not only the extreme delicacy of this test for sewage pollution, but shows a very considerable improvement in the sanitary quality of the water occurs between Pekin and Grafton, notwithstanding the large amount of pollution at Pekin. Comparing the condition of the water in the Mississippi River above Grafton with that in the Illinois River above Grafton, as evidenced by the colon content of these two waters, it appears that the colon bacillus was present in 5 per cent. of the determinations made of .01 c. c. of water from these two places.

It may be mentioned that 117 determinations were made of the Illinois River water above Grafton and 115 of the Mississippi water above Grafton during this period, so that the substantial agreement in percentage shown in the sanitary character of these waters during this period has a satisfactory statistical basis.

Comparing the examinations made of .1 c. c. of water during this same period, it is shown that 24 per cent. of the samples from the Mississippi River yielded positive results, while 13 per cent. of those from the Illinois River above Grafton yielded positive results.

In .1 c. c. of water from these two stations 38 per cent. of the samples from the Mississippi River and 30 per cent. of those from the Illinois River gave positive results.

In other words, so far as any conclusion as to the sanitary character of these waters can be drawn from the colon determinations—and I have already indicated that in my opinion and in that of sanitary experts generally, the colon test is the most delicate and satisfactory clue that we have to the sanitary condition of the water—the water of the Mississippi River above Grafton during this period was,

if anything, of a less wholesome character than the water of
6122 the Illinois River above Grafton.

Comparing further the colon content of the Missouri River water above Bellefontaine during this period, it is shown that 19 per cent. of the .01 c. c. samples were positive as compared with 5 per cent. in the Illinois River at Grafton, and that 50 per cent. of .1 c. c. samples were positive as compared with 13 per cent. in the Illinois River at Grafton, and that 79 per cent. of the 1. c. c. samples were positive as compared with 30 per cent. in the Illinois River above Grafton.

Comparing the percentages of positive results obtained in the examination of 1. c. c. of water in cross-section at chain of rocks, it appears that there was a smaller percentage of colon bacteria in the Mississippi River on the Illinois shore and in mid-stream than at the intake tower and on the Missouri shore. This confirms the difference already noted between the colon content of the Illinois River and the Mississippi River at Grafton and that of the Missouri River at Bellefontaine. The higher colon content of the Missouri River betrayed itself in the larger number of colon bacilli found in the Mississippi River at the intake tower and near the Missouri shore at the chain of rocks.

The sanitary significance which I attach to these findings is based on what I have been able to learn by my own observation and experiments regarding the significance and relative abundance of the colon bacillus in waters of various kinds, as well as that derived from an examination of the available literature on the subject and the opinions of various sanitary experts already referred to in my testimony. It may be summed up by the statement that the water from the Missouri River during this period was distinctly more dangerous and unwholesome than the water of either the Illinois or the Mississippi River at Grafton, and further, that the difference between the Illinois River above its mouth and the Mississippi River above Grafton, while
not great, shows that on the whole the Illinois River was in a
6123 less highly polluted condition than the Mississippi.

Jeffries' repudiation of the agreement between the City of St.
Louis and the Sanitary District for the making of the fore-
6123-6125 going determinations.

Photographs of fermentation tubes showing the difference in the amount of gas production from samples of water taken from the
Missouri River at the chain of rocks and from the Missouri
6120-6130 River at Bellefontaine.

Q. What is the character of the different waters?

A. The character of these waters during this period, as shown by the colon examinations, and as set forth in the tables and illustrated by the photographs, is quite different. The colon content of the Missouri River is markedly higher than that of either the Illinois or the Mississippi River at Grafton, and from this I infer that during this period the Missouri River was more highly charged with dangerous bacteria and was distinctly less safe than the water of the Illinois River.

Under these conditions the effect of any mixture of the Illinois River water with the Missouri River water at the intake tower of the St. Louis waterworks would therefore tend to diminish the colon content of the water at that point, thereby rendering it less dangerous for human use. Such mixing of the Illinois and Missouri waters as took place would hence improve the conditions existing during
6132 this period in the Mississippi River at the intake tower.

Q. Professor, Mr. Allen Hazen, on page 4530 of the record, was asked this question, "When the mixing begins at the mouth of the Illinois River, by the time it gets to the mouth of the Missouri River, is that mixing complete?" and he answered, "I do not think it is absolutely complete. It is approximately so; more so at low water than at high water." What do your bacterial analyses show as to whether there is more mixing of these waters at low water than at high water?

A. I may state in reply that in my opinion the total number of bacteria in the water at the intake tower and near the Missouri shore at the chain of rocks, as well as the number of colon bacteria in the water at these points, shows conclusively that during this period of low water the water collected at these two stations was almost wholly, if not altogether, Missouri River water, and was mixed little, if any, with the water from the Illinois. If it be true, therefore, that mixing is more complete at low water than at high water, it will certainly follow that the amount of Illinois River water present in the Mississippi at these two points at high water stages must be
6133 exceedingly small.

Q. Do you know whether it is the usual practice in this country among analysts to make daily and hourly determinations of a river water for a long period of time in order to determine the sanitary quality of such water?

A. Reference to some of the recent studies of river water that have been made in this country shows that opinions have been formed and judgments passed on the sanitary character of river water on a smaller number of determinations than would be involved in hourly

or even daily examinations. Thus I find the report on water purification investigations carried out under the direction of Mr. G. W. Fuller, in behalf of the sewage and water board of New Orleans, Louisiana, the report being published in 1903, a series of tables showing the turbidity, alkalinity and chlorine contained in the Mississippi River water from October 1, 1900, to December 15, 1900 (page 38).

I also find a series of tables showing the composition of the Mississippi River water as determined by its examinations between December 10, 1900, and August 17, 1901.

In another recent investigation of the composition of river water contained in the report of the Filtration Commission of Pittsburg, Pennsylvania, printed in 1889, I find a series of investigations conducted under the supervision of Mr. Allen Hazen, who, I believe, has already testified in this case. In Appendix No. 2 of this report, I find the statement, "It was desired especially to learn about the character of water obtained from various cribs in the Alleghany River."

In the next paragraph the statement appears, "The samples of the Alleghany River at Brilliant were collected about once a week from the beginning of the work until about March 1, 1898. For the next three months samples were collected once a week until the close of the experiments."

From what I know of the work of Mr. Fuller and Mr. Hazen, I infer that these gentlemen, who have had large experience in undertakings of this character, would not have had these examinations of river water carried out under their direction at daily and weekly intervals during portions of the calendar year if they had not believed that such determinations actually give a basis for a fairly satisfactory judgment of the character of a river water. Mr. Fuller's examinations at Louisville and at Cincinnati, while extending over a longer period, are substantially of the same character as those in the later investigations.

In European countries, so far as I know, no extended examinations of river water, based on daily and weekly analyses, have been made, which cover so long a period of time as those that have been made in this case.

It is, therefore, my opinion that the usual practice of those experts having to do with the examination of river waters in this country is based on the belief that an adequate opinion as to the character of the water can be formed by examinations made at intervals as frequent and during periods as long as those indicated in the in-

6136 stances just cited.

Q. What period of time have your own analyses covered throughout this investigation?

A. The examination which I have made in behalf of the Sanitary District of Chicago covered two periods, the first one of weekly examinations, extending from about the 1st of May, 1899, to the first of July, 1900. During this period the regular weekly examinations were supplemented by daily, and in some instances hourly, examinations of the river water at several points; the second period includes daily examinations made between about the first of November, 1901, to about the first of January, 1902. In all the examinations that I have made, cover a period of one year and five months.

Q. In your opinion, is it possible to pass a competent judgment upon the waters of the Illinois, Mississippi and Missouri Rivers on the basis of the analyses you have submitted in your testimony?

A. It is decidedly my opinion that such is the case. The analytical data, chemical and bacterial, that I have secured by these weekly, daily and hourly determinations, extend over a sufficient interval of time and include sufficiently varying conditions to permit of a satisfactory judgment being rendered as to the general character of the waters dealt with. The separate analyses number many thousands, and the results embody the experience gleaned from a study of high water and low water conditions, of summer and winter temperature, and of varying climatic and meterological factors. It is my judgment that, taking into consideration the analyses made concurrently by Professors Palmer, Long, Zeit, Gehrmann and Burrill, no such extensive and exhaustive study of river water, in connection with the problem of self-purification of streams, has ever been made anywhere
6137 in the world as that carried out during this period.

Q. How did the Illinois River compare with the Missouri River after January 17, 1900?

A. The relative character of the two rivers was not materially different from the 17th of January, 1900, to the 1st of July, 1900. That is to say, the Missouri River water was more objectionable from a sanitary standpoint than the water of the Illinois River at its mouth or at Averyville.

Q. How did the Illinois River compare with the Missouri River for the period of 1901?

A. During the period October—December, 1901, when daily examinations were made and a large number of results obtained, the sanitary quality of the Missouri River water was, in my opinion, distinctly inferior to the Illinois River water at its mouth and at Averyville, as shown especially by the colon determina-
6138 tions.

Q. What sanitary significance do you attach to your chemical

and bacterial analyses, including the colon tests, colony counts and species determinations heretofore introduced into evidence, as evidenced by the tables and charts and photographs already introduced by you?

A. Taking into consideration all the analytical data that I have obtained throughout the seventeen months covered by the investigations, I conclude that one of the most remarkable facts, if not the most remarkable, is the entire concurrence of the results derived from the chemical and the various bacterial determinations. The amount and rate of nitrification in the water of the Illinois River at various points along its course, as shown by the tables of chemical analyses, are in line with what the experience of water analysts has shown to accompany a real purification. The large amount of organic matter present in the upper stretches of the Illinois River is oxidized during its passage down stream, and before Averyville is reached the nitrification of this organic matter has progressed practically to completion.

On the bacterial side, the evidence is wholly confirmatory of this improvement in the quality of the Illinois River water. The enormous number of bacteria poured into the Illinois River in its upper stretches, as shown by the number of bacteria present in the Illinois River at Lockport and Joliet, is greatly diminished in a flow of less than one hundred miles. Under certain conditions even, and at certain periods of the year, the Illinois River becomes nearly free from the great mass of sewage bacteria with which it was originally laden in as short a distance as twenty-four miles, as evidenced by the observations between Morris and Ottawa, already introduced. Both at Averyville and above Grafton the bacterial composition of the Illinois River water is about the same as that of tributary streams and as that of the Mississippi River just above Grafton. The colon contents of the Illinois River water is, in my opinion, especially significant from a sanitary point of view, and affords evidence in entire harmony with the conclusions derived from the chemical examinations and from the number of bacteria of all kinds shown to be present in these waters. The colon bacteria which are found in great abundance in the waters of the drainage canal and in the upper stretches of the river practically disappear before Averyville is reached.

It is clear from the data that I have presented that the water of the Illinois River undergoes a real and very considerable purification. The colon bacteria which are shown to be present in large numbers in Chicago sewage disappear almost completely in less than 150 miles flow. At the mouth of the Illinois River, despite the enormous initial

pollution and the very large secondary pollution at Peoria, the number of colon bacteria is certainly no greater than the number in the Mississippi River at this point, and not as large as the number in the Missouri River at Bellefontaine. Since all investigators are agreed that the colon bacillus is more hardy than its relative, the typhoid bacillus, and can live in water for a longer time, there is every reason for supposing that the latter microbe dies out with at least the same rapidity. If it be true, as I firmly believe to be the case, that the fate of the colon bacillus in running water furnishes the most satisfactory indication we can secure at present of the continuance of vitality of the typhoid bacillus, there can be no hesitation as to the conclusion to be drawn from this investigation. Since this biological relative of the typhoid bacillus perishes speedily and in large numbers in the course of the Illinois River, it is my opinion that the typhoid
6140 bacillus itself cannot long survive exposure to the same conditions.

BACTERIOLOGY.

Bacteriology classified and distinguished. Manner of distri-
6140 bution.

Characteristics of the bacteria peculiar to water. Saprophytes
6141 and parasites distinguished.

Distinction between non-pathogenic and pathogenic bacteria. Bacteria that are known to be pathogenic to man. Pathogenic bacteria that are water borne and find their way into the human
6142 body in drinking water.

Bacillus prodigiosus. Its characteristics and life history. Found in river water.

Q. Have you found it in the waters of the Illinois River?

A. On November 6, 1899, I isolated from the water of the Illinois River, collected at Morris, an organism which in all the characteristics I have described resembles exactly the bacillus prodigio-
6143-6144 sus et seq.

Table of comparison of bacillus prodigiosus of a germ labeled B. 210 isolated from the Mississippi River near the Missouri shore with B. prodigiosus from the University of Michigan, Yale
6146 University and Ontario Board of Health.

Organisms found in the Illinois, Mississippi and Missouri
6148 Rivers, resembling prodigiosus.

Q. Professor, have you read the testimony of Mr. Ravold, wherein he detailed the result of what is known as his prodigiosus experiment?

A. Yes, sir; I have read his testimony as it appears in the record of this case.

Q. What importance, as a bacteriologist, do you attach to the value of that experiment, as given in the record of the evidence in this case?

A. It seems to me to constitute a demonstration of the power of self-purification in streams, from the fact that along the upper collecting stations in the Illinois River this organism was not recovered, although frequent examinations were made of the water at these points, and although, according to the testimony, prodigious numbers of this organism were introduced into the water of the drainage canal.

As regards the finding of a few individuals in the water of the Mississippi River, assumed to be of the same variety as that introduced, I can only say that the identification does not appear from the records to be altogether complete. And, furthermore, assuming that the organisms recovered from the Mississippi River were actually those introduced in the drainage canal, the appearance of so small a number would not in itself be significant. This is true especially since organisms belonging to this prodigiosus group, as has been shown, are sometimes found in the water of the rivers and are saprophytic forms which are evidently rather easily habituated to

6149 aquatic life.

Characteristics and pathogenic significance of the cholera germ.

Characteristics and pathogenic significance of the tetanus

6152 germ.

6152 The tetanus germ is not a water-borne infection.

6152 Charactertistics and pathogenic significance of the anthrax germ.

TYPHOID BACILLUS.

Characteristics and pathogenic significance of the typhoid

6154 germ.

Where the typhoid germ is found and its resemblance to other

6155 germs, together with its relation to the colon bacillus and methods of differentiating and identifying the typhoid bacillus.

The longevity of the typhoid bacillus in the human body com-

6156 pared with its longevity in soil and water.

The established instances where the typhoid bacillus has been

6156-58 detected in potable water.

Investigations of the longevity of the typhoid bacillus in dif-

6159 ferent kinds of water in laboratory experiments.

The typhoid bacillus does not multiply and increase in nature.

The conditions of a laboratory experiment are decidedly more favorable to the longevity of a typhoid bacillus than the conditions that obtain in nature. Reasons for this view stated.

6159 Will the germ of typhoid live as long in polluted water as in pure or sterilized water?

A. No, sir; I think it will live longer in pure water than in polluted water, and it is well known from the experiments of many observers that it lives longer in sterilized water than in unsterilized.

Q. How do you account for this?

A. I attribute the relatively speedy death of the typhoid bacillus in polluted water, as compared with pure and in unsterilized water as compared with sterilized to the action of the various saprophytic microbes which inhabit these waters. W here the typhoid bacilli are removed from competition with these saprophytic forms, as in the case where they are introduced into sterilized waters, they live longer than under the conditions where they may be injuriously infected by the products of other microbes. In the case of the polluted waters the greater concentration of organic matter may favor a more intense action of the products of the saprophytic microbe present in these waters. In other words, these products in the polluted water are in more concentrated form than is the case in the pure water, and so bring about the death of the typhoid bacillus sooner. It is therefore to the action of the saprophytic microbes that I attribute the dying off of the typhoid bacillus in polluted waters and in unsterilized waters.

6160 Q. From your knowledge of the character and quality of the water of the drainage canal, the Desplaines River and the Illinois River, what is your opinion as a bacteriologist as to the longevity of the typhoid bacillus in these waters?

A. From what I know of the chemical composition and bacterial contents of the waters of the Illinois River at various points along its source, it is my opinion that the life of the typhoid bacillus introduced into the Illinois River at the upper end of drainage canal would not be more than three or four days.

Q. What reasons have you for the opinion that the life of a typhoid bacillus in the waters of the drainage canal, the Desplaines and the Illinois Rivers is shorter as compared with the laboratory experiments?

A. In the water of the Desplaines and Illinois Rivers the typhoid bacillus is subjected to the unrestricted action of the products of the various saprophytic microbes that inhabit these waters. The large amount of organic matter in the upper stretches of the river

favors the concentration and the consequent intensity of action of these saprophytic products. As compared with the laboratory conditions again, the typhoid bacillus can hardly be favored in these rivers by the presence of any such substances as go into solution from the glass bottles used in laboratory tests. These two reasons, therefore, the absence of the favoring laboratory conditions and the free and vigorous action of the products of growth of saprophytic microbes, lead me to adopt the opinion that I have just ex-
6161 pressed.

Familiarity of the witness with the Chicago River, the Illinois River, the Mississippi and Missouri Rivers and the opportunity of becoming acquainted with the watershed from Chicago to St.
6161-65 Louis.

Description of the physical condition of the Illinois River and
6163 its tributaries.

Effects of the lakes along the Illinois River between Chicago and Grafton as factors for the elimination of infection and
6163 pollution entering the Desplaines River.

Other sources than the drainage canal supplying pollution to
6164 the Desplaines and Illinois Rivers.

Importance attached to the dams and lakes and physical conditions of the river as a factor in the purification of said stream at all times and under the conditions that obtain in the Illinois
6165 River.

The effect of clear water as compared with turbid water con-
6165 taining matters in suspension as affording an opportunity for sedimentation.

Q. Is the degree of sedimentation in the Illinois River affected by diluting the sewage of Chicago with Lake Michigan water?

A. There is at times a considerable amount of suspended matter in the water of Lake Michigan near the mouth of the Chicago River, but on the whole the water of Lake Michigan is not a turbid water. In that portion of the Illinois River, however, where most sedimentation obtains the amount of suspended matter introduced into the water from the tributaries and entering the river directly is, in my judgment, sufficient to affect the same degree of sedimentation that would occur if the present amount of dilution with Lake
6166 Michigan water at the extreme upper end of the river was absent.

Q. What significance does dilution have in considering the problem of the self-purification of streams?

A. When polluting or infectious matters are added to a water

it naturally follows that the greater the dilution of such matters the less dangerous is a given quantity of such water, such, for instance, as a quart or a liter. In this sense dilution with a purer water may be said to increase the purity of the stream. So far as the actual destruction of infectious elements is concerned, dilution to such an extent as usually occurs probably has but little influence.

6167 Q. Is the danger of infection really diminished by dilution?

A. It certainly is.

Q. In what way?

A. Suppose that infectious material was introduced into sewage to such an extent that each tumblerful of the sewage contained one typhoid bacillus. Suppose further, that such sewage were diluted with nineteen times its bulk of pure and uninfected water, it would then be true that out of one hundred glasses of this mixture of sewage and pure water only five would contain typhoid bacilli instead of the whole one hundred, as was originally the case. In other words, the same effect is obtained as if 95 per cent. of the typhoid bacilli perished. In this way dilution unquestionably diminishes the danger from infection.

Q. What effect does the dilution of Chicago sewage with the pure water of Lake Michigan have upon the condition of the water in the Illinois River?

A. Considering the conditions at the mouth of the Illinois River above Grafton, I should say that such dilution has little if any effect upon the infectious quality of such water, since whether the sewage be diluted or not death of any typhoid bacillus originally present therein would occur, in my opinion, long before the mouth of the Illinois River was reached. Considering the character of the Desplaines River at Joliet, however, such dilution would diminish the danger to any person venturesome enough to partake of the fluid at this point, since the dilution would diminish the number of typhoid germs contained in a given quantity, say a tumblerful of the

6167-68 mixture.

Q. Is the addition of Lake Michigan water to the sewage of Chicago a detriment or benefit to the sanitary condition of the Illinois River in its upper branches, considered from the standpoint of dilution alone?

A. If by sanitary conditions is meant the infectivity of a given measured quantity of water, such dilution would improve the Illinois River water in its upper stretches. So far as the destruction of typhoid bacillus is concerned, it is my opinion that this dilution has little or no influence upon the longevity of this microbe. The actual

number of typhoid bacilli passing a given point would not be
6168 materially influenced by dilution, but the proportional number in a given quantity of water would of course be lessened.

Conduit Question of Professor Sedgwick.

Assuming the question as quoted to apply to the passage through a conduit of the water of Lake Michigan from the lake front at Chicago to the Mississippi River at Grafton, I would say that I do not consider that it would be a menace or danger to the State of Missouri, and especially to the citizens of St. Louis, drinking the Mississippi River water in its raw condition. I make this answer because in my opinion the typhoid bacillus would not survive exposure to the conditions in such a closed conduit, any more than in my opinion it does survive exposure to the conditions existing in the Illinois River. * * * Assume the condition in the Missouri and Mississippi Rivers to be as they are at present, it is my judgment that the water issuing from such a conduit and experiencing the same degree of purification which now takes place in the Illinois River, would tend rather to improvement and purification of such water so far as it might mingle with it.

6169-70 The Illinois River in comparison with other rivers in the country for the purpose of purification.

Professor Sedgwick's description of the Allegheny River from
6170-71 Oil City to Pittsburg.

Comparison of the Illinois with the Allegheny River as puri-
6172 fication streams.

Q. Professor Sedgwick, on page 369 of the transcript of his testimony, an uncorrected copy of which I have, stated: "The River Commissioners of Great Britain, in a report published by them in 1874, state there is no river in England long enough to purify itself from any sewage admitted to it, even at its source"; that stands as one of the axioms of sanitary science today, that those River Commissioners, in 1874 I think it was, made that statement, that there is no river in the United Kingdom, I think they said, long enough to purify itself of any sewage introduced into it, introduced at its source, and of course some of the rivers of the United Kingdom are very long. And again, on page 4398, this question was asked him: "Do you know how the distance from Cumberland to Washington by river compares with the length of the River Thames in the United Kingdom?" answered, "The Thames is 209 miles long, and is, I believe, the longest river in the United Kingdom, and this epidemic seems to confirm in a very remarkable way that statement of the Rivers Pol-

lution Commission of Great Britain to which I have referred in my previous testimony where they said that there was no river in the world that was long enough to purify itself of any sewage introduced into it, even at its source." I will ask you if you are familiar with the report of the River Pollution Commission of Great Britain for 1874?

A. Yes, sir, I have frequently consulted it in connection with my teaching and investigation work.

Q. Will you state what the River Pollution Commission report for 1874 did state about river purification?

A. The statement is as follows:

"It will be safe to infer, however, from the above results that there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation."

Q. What is the difference between the expression, "to effect
6173 the destruction of sewage by oxidation," and the expression "to purify itself of any sewage introduced into it at its source"?

A. At the time this report was published, in 1874, the knowledge of sanitarians regarding the quality of water was based on chemical data, this being before the rise of the science of bacteriology. Practically nothing was known at that time regarding the elements in sewage that imparted to it its dangerous character. The fact had, however, been determined empirically that a certain relation existed between the oxidation of sewage and the loss of its dangerous qualities. It was not known, however, precisely what this relation was or upon what it depended. At the present time our conception of the purification of a sewage polluted stream is based rather upon what information we are able to obtain regarding the disappearance and destruction of disease producing bacteria that may be introduced into it rather than upon oxidation processes. There is, therefore, a wide difference between stating that the purification of a stream is effected within a certain distance and that the destruction of sewage by oxidation is accomplished within a certain distance. It does not, by any means, follow that because complete destruction by oxidation of the organic matters contained in a sewage polluted water does not occur within a specified distance that the real purification of the sewage, that is to say its freedom from dangerous bacteria, may not be accomplished within that distance. It is certainly true that the process of nitrification or oxidation and the processes leading to
6174 the disappearance of dangerous or suspicious bacteria do not always run in a strictly parallel course either in sewage tanks or polluted rivers.

Q. From your knowledge of the physical conditions that obtain along the Illinois River, as well as your analyses of the water, both chemical and bacterial, what effect, if any, does the sewage from Chicago, discharged into the drainage canal, have upon the waters of the Mississippi River as the same passes along the shore of the State of Missouri?

A. The large amount of harmless inorganic chlorine in the water of the Illinois River at its mouth is derived chiefly from the sewage of Chicago and Peoria. So far as the water of the Illinois mingles with that of the Mississippi along the Missouri shore, so far is the chlorine content of the water heightened. In respect to other constituents of the Illinois River water, the sewage introduced at Chicago influences the total amount of nitrogen compounds in said water. This is especially true of the nitrates, which are usually high at Grafton. In respect to the bacterial content of the water, the mixing of the Illinois with the Mississippi does not, in my opinion, introduce into the mixture any significant number of bacteria derived from the sewers of Chicago. It is my opinion that practically all
the bacteria introduced into the drainage canal from the Chi-
6176 cago sewers perish long before the mouth of the Illinois is reached.

I conclude that the sewage from Chicago, introduced into the
6176 drainage canal, has no injurious effect upon the waters of the Mississippi as the same passes along the shore of the State of Missouri.

Q. What evidence have you that justifies the conclusion just expressed, that no pollution dangerous to public health, coming from the sewers of Chicago, reaches as far down the Illinois River as Grafton?

A. All the analytical data that have been introduced by me in evidence justify, in my opinion, the conclusion that I have expressed, the rate of oxidation of the organic matters in the sewage, the enormous death rate among the sewage bacteria in the extreme upper reaches of the Illinois, and especially the high mortality among the colon bacilli, all combine to furnish convincing evidence that pollu-
tion dangerous to public health, coming from the sewers of
6177 Chicago, does not reach as far down the Illinois River as Grafton.

I know of no evidence, bacterial or chemical, that would justify the conclusion that polluted and infected matter coming from the sewers of Chicago will reach as far down the Illinois River as the town of Grafton. On the contrary, as I have stated, the evidence of

which I am cognizant points to precisely the opposite conclusion, namely, that such deleterious elements do not reach as far down the Illinois River as the town of Grafton.

Professor Sedgwick's question as to whether it is within the
6178 bounds of human possibility for any expert to say that in a period of low water on the Missouri River, etc.

6179 Professor Jordan's reply to that question.

From my knowledge of the conditions indicated in your question, it is my judgment that the sewage of Chicago has no injurious or deleterious effect upon the water supply of the City of St. Louis or upon the water of the Mississippi River as it passes along the
6179 shore of the State of Missouri.

Q. Will you state upon what facts you base your opinion that a typhoid bacillus will not live more than three or four days under conditions as they obtain in the drainage canal, the Desplaines River and the Illinois River?

A. I base my opinion chiefly upon the elaborate experiments that I have recently carried out on the life of the typhoid
6180 bacillus under natural conditions in the waters of the drainage canal at Robey street at Lockport.

Experiment on the life of the typhoid germ under natural
6180 conditions.

Method of conducting the experiment.

Description of parchment sacs in detail and the manner of
6181-82 suspending them in the Chicago River and drainage canal.

The other part of the experiment was conducted by Prof. Zeit and Prof. Russell, but the general plan of the experiment and the details were disclosed for view by us before the work was un-
6183 dertaken, and the experiment was conducted independently under the control of each investigator.

Description in detail of the manner in which experiments were
6183 made.

Typhoid germs used in this experiment were taken from three patients from the Cook County Hospital, and the description
6183-4-5 with the diagnosis and history of the diseases of each patient.

The aim of isolating these cultures in a fresh condition from the body of patients was to obtain the maximum degree of vitality and virulence, thus making the outcome of the experiment,
6186 whatever it might be, as valuable as possible from a scientific point of view, and as conclusive as possible on the sanitary side.

6187 Methods employed in developing the typhoid germs isolated from the patients.

6187-88 Reasons for the selection of parchment sacs for use in this experiment.

Q. How many sacs of the character you have described were employed in making this experiment?

A. At Robey street 16, at Lockport 12. These were all inoculated sacs, that is, sacs into which typhoid bacillus were introduced. In addition a number of sacs were introduced into the water at both Robey street and Lockport which were filled with the sewage taken directly from these places, and were used as control sacs.

6189 Control sacs explained.

6189 Method of inoculating these sacs with typhoid bacilli.

After the sacs were inoculated and suspended in the water samples were collected in sterilized glass bottles and taken to the bacteriological laboratory of the University of Chicago.

Q. After the samples were brought to the University of Chicago laboratory what was done with them?

A. Accurately measured quantities of the sewage into which typhoid bacilli had been introduced were mingled with special nutrient media of various kinds, and the mixture poured out into sterilized glass dishes. The amount of sawage used was such that a suitable separation of the colonies developing on these plates was arrived at.

6190 On the following day these colonies were examined by me and my assistants, and any colonies that resembled typhoid colonies were taken from the plates and subjected to a searching examination.

6191-94 Methods employed in the identification of colonies.

6196 Method for the identification of the typhoid bacillus in the experiment.

6198-6205 Tables of bacterial results made from the analyses of water in the drainage canal at Lockport.

6208-6223 Tables of bacterial results at Robey street.

6223 Purposes of the control sacs.

6224-27 Table of bacterial analyses of control sacs.

To sum up, the conditions shown by these control sacs, the behavior of the bacteria is shown to be practically identical with what I have seen reason to believe is the natural course of events in the sewage polluted stream itself. There is at first, perhaps, a slight increase in the number of sewage bacteria, while the colon bacilli apparently hold their own for about twenty-four hours. There is then a marked and continuous decline in the number of ordinary sewage

bacteria as determined by the colony count and also in the number of colon bacteria and streptococcus, thus simulating in a very precise fashion the changes that take place in the canal and river water.

I regard the evidence presented by these control sacs as confirming altogether the inferences which I have already drawn concerning the naturalness of the conditions in these parchment sacs. The course of events, so far as the death of sewage bacteria and colon bacteria are concerned, is precisely the same as what I have been led to consider happens in the river when these sewage bacteria are added to it in Chicago sewage. In both cases there is the same marked
6228 diminution in the number of sewage bacteria and in the number of colon bacilli.

6229 Table of summaries at Lockport.

Q. Will you explain the table of summaries and state what it shows?

A. This table of summaries of the experiment made in the drainage canal at Lockport, on this sheet, headed, "Drainage Canal at Lockport," which has just been read in evidence, shows the combined results of the several experiments. One sample was taken ten minutes after inoculation, and out of 68 colonies examined 63 were typhoid. One day after inoculation out of 93 colonies examined none were typhoid.

2 days after inoculation, out of 165 colonies examined, none was typhoid.

3 days after inoculation, out of 242 colonies examined, none was typhoid.

5 days after inoculation, out of 136 colonies examined, none was typhoid.

6 days after inoculation, out of 17 colonies examined, none was typhoid.

7 days after inoculation, out of 119 colonies examined, none was typhoid.

8 days after inoculation, out of 24 colonies examined, none was typhoid.

9 days after inoculation, out of 59 colonies examined, none was typhoid.

10 days after inoculation, out of 110 colonies examined, none was typhoid.

6231 The total number of colonies examined after the date of inoculation was 924. In this number no typhoid colonies were found.

6232 Table of summaries at Robey street.

Q. Will you explain what that table of summaries at Robey
6234 street shows?

A. The table contains the summarized results of the experiment conducted in the water of the drainage canal at Robey street. Combining the results obtained from the several sacs the following totals appear:

1 hour after inoculation, out of 49 colonies taken, 41 were typhoid.

20 hours after inoculation, out of 104 colonies taken, 41 were typhoid.

28 hours after inoculation, out of 118 colonies taken, 89 were typhoid.

I may say at this point that the reason why a larger proportion of colonies were found in the 28-hour samples than in the 20-hour samples was because a larger quantity of water was examined or plated, and this, of course, resulted in the appearance of a larger number of typhoid like colonies on the plate.

After 2 days' inoculation, out of 221 colonies examined, 10 proved to be typhoid.

3 days after inoculation, out of 142 colonies examined, none proved to be typhoid.

4 days after inoculation, out of 193 colonies examined, none proved to be typhoid.

5 days after inoculation, out of 127 colonies examined, none proved to be typhoid.

6 days after inoculation, out of 133 colonies examined, none proved to be typhoid.

7 days after inoculation, out of 139 colonies examined, none proved to be typhoid.

8 days after inoculation, out of 76 colonies examined, none proved to be typhoid.

9 days after inoculation, out of 102 colonies examined, none proved to be typhoid.

10 days after inoculation, out of 96 colonies examined, 3 proved to be typhoid.

11 days after inoculation, out of 33 colonies examined, none proved to be typhoid.

12 days after inoculation, out of 75 colonies examined, none proved to be typhoid.

14 days after inoculation, out of 50 colonies examined, none
6234 proved to be typhoid.

Q. Did you make any experiments supplementary to the experiment that you have heretofore introduced into evidence?

A. Yes, I have made some experiments comparing the parchment sacs with the celloidin sacs.

Q. Will you describe the manner in which this experiment was made?

A. Large celloidin sacs were prepared by my assistant, Dr. Harris, who has had special experience in making these. They were made of the same size as the parchment sacs used in the experiments hereinbefore described, and for the sake of having a comparison as to the course of events in these sacs some preliminary tests were made in the laboratory. The parchment sac and the celloidin sac were placed under identical conditions in large glass vessels and a stream of lake water from the tap allowed to pass continuously through the glass vessel, so that the temperature was kept constant and the conditions surrounding the sacs were the same. Bacillus typhosus, the strain previously designated as Y, was added to lake water in such numbers that each sac contained, approximately, 3,080 typhoid bacilli per cc. The original number of bacteria in the lake water, as determined by the usual colony count, was 65.

1 day after inoculation of the parchment sac 21 colonies were picked off, 19 of which proved to be typhoid.

In the celloidin sac 1 day after inoculation out of 16 colonies picked off 6 were typhoid.

2 days after inoculation of the parchment sac out of 20 colonies picked off the plate 9 were typhoid.

In the celloidin sac 2 days after inoculation out of 20 colonies picked off the plate 2 were typhoid.

3 days after inoculation of the parchment sac out of 20 colonies picked off the plate 5 were typhoid.

3 days after inoculation of the celloidin sac out of 20 colonies picked off the plate none was typhoid.

4 days after inoculation of the parchment sac out of 20 colonies picked off the plate 1 was typhoid.

4 days after inoculation of the celloidin sac out of 20 colonies picked off the plate 1 was typhoid.

On the fifth, sixth, seventh, eighth, ninth, eleventh, twelfth, thirteenth and fifteenth days after inoculation, out of 177 colonies examined, an average of about 20 per day, and the same number were examined from the celloidin sac. In no case, however, was the typhoid bacillus found later than the fourth day.

This experiment shows several points of interest.

1. The validity of the methods of isolation used is again dem-

onstrated by the large proportion of typhoid bacilli obtained in the early days from suspected colonies.

The total number of colonies appearing on the plate was very large on the third and fourth day of the experiment, reaching to upwards of 120,000, in spite of the fact that a relatively small number of typhoid bacilli had been added originally, namely, 3,080. The isolation of the typhoid bacilli did not prove to be difficult. This seems to be a most striking demonstration of the great value of the special media employed.

2. In the second place, it may be noted that the typhoid bacilli lived about twice as long in this experiment in the lake water as they did in the water of the drainage canal at Robey street.

3. In the third place, the essential similarity between the sacs shows that the conditions surrounding the bacilli are substantially the same, whether they are imprisoned in parchment or in celloidin. This was perhaps to be expected since both the celloidin and the parchment have long been used for work in dialysis, and since both allowed bacterial toxins and other soluble products to pass free

6235-36 through their walls while strictly confining the bacilli.

Q. Professor, did you make a.y other comparative experiments?

A. Yes, sir, I compared the behavior of sewage kept in parchment and celloidin sacs, and kept under the same conditions.

Q. Will you describe that experiment?

A. Fresh sewage obtained from the Fifty-sixth street sewer in Chicago was placed in parchment and celloidin sacks, suspended in running lake water in the laboratory, as described in the experiment just cited. The initial number of sewage bacteria, as determined by the colony count, was 500,000, the number of B. coli per cc. from 70,000 to 90,000, the number of streptococcus per cc. about 30,000.

A multiplication of the sewage bacteria occurred in the first day, the number in the parchment and celloidin sacks rising to a little over 2,000,000. This was followed in the next twenty-four hours by a marked decline in the number of bacteria shown in the colony count. The number of colon bacteria and streptococci remained about the same through the first three days and then diminished very greatly.

After seven days the count showed in the parchment sacks 64,500 bacteria per cc., 1,000 bacilli coli per cc. and 100 streptococci per cc. In the celloidin sack the total number of sewage bacteria was 10,200; the number of B. coli 500 to 700; the number of streptococci 300.

The other examinations, made on the third, fourth, fifth, sixth,

seventh, eighth, tenth and twelfth days, showed essential similarity between the course of events in the parchment and celloidin sacks, thus confirming what was observed in the preceding experiment.

I conclude that the conditions in the parchment and celloidin
6237 sacks are substantially identical.

Q. From the result of this experiment what conclusion do you draw as to the longevity of a typhoid bacillus in the water of Lake Michigan?

A. It was found by actual experiment under conditions which I believe to simulate those in nature that the typhoid bacillus introduced into unsterilized Lake Michigan water was recovered four days after inoculation, and was not found in subsequent examinations made up to the end of the fifteenth day. It is probable that specially persistent cells might survive longer than appeared to be the case in the experiment described in my testimony, but in my opinion even such highly resistant individuals, if they did exist, would not live more than about twice as long as the time recorded in these experiments. So that I conclude that eight to ten days would be a maximum period of longevity for the typhoid bacillus in the water of Lake Michigan under natural conditions.

Q. From the result of these experiments what conclusion do you draw as to the longevity of the typhoid bacillus in the water of the drainage canal?

A. These experiments, of which a large number were made with varying numbers of typhoid bacilli introduced directly into the water of the drainage canal, gave generally uniform results. It was not difficult to discover typhoid bacilli during the first two days. Later than that they were never found, either at Lockport or at Robey street, with one exception. In this anomolous case three typhoid bacilli were isolated on the tenth day from a single plate in a single sack.

Taking into consideration all of the experiments made in the waters of the drainage canal, and assuming, as before that specially resistant individual cells might exist, which would live twice as long as those found, it is my opinion that typhoid bacilli introduced into the waters of the drainage canal, under natural conditions, would not and do not live in that situation longer than four days.

Q. From the result of these experiments, what conclusion do you draw as to the longevity of typhoid bacilli in the water of the Illinois River?

A. Remembering that the upper stretches of the Illinois River are highly polluted with sewage, and that considerable additions of

sewage are made to the Illinois River at points along its course, I do not believe that bacilli introduced into the Desplaines or upper portion of the Illinois River would live under natural conditions more than five or six days.

Q. What, in your opinion, would be the fate of a typhoid
6239 bacillus passing from the sewers of Chicago into the Chicago River and thence into the drainage canal and down the Desplaines and Illinois Rivers?

A. It is my opinion that a typhoid bacillus, discharged from the body of a typhoid patient in Chicago, and assuming that such discharges were not disinfected so that the bacillus could pass into the sewers of Chicago and thence into the Chicago River and drainage canal, might live as long as three or four days after leaving the body of the patient.

From what I know of the rate of flow in the drainage canal and in the Desplaines and upper Illinois rivers, in my judgment such a typhoid bacillus would perish long before Averyville was reached, even at a period of low temperature and high water.

Q. From a scientific standpoint, what value do you attach to this experiment as showing the longevity of a typhoid bacillus in polluted water?

A. I regard the experiment as described as shedding a great deal of light upon the life of the typhoid bacillus under natural conditions.

The results, in my opinion, show quite conclusively that if any typhoid bacilli survive later than forty-eight hours after they have been introduced into the highly polluted waters of the drainage canal they must be highly resistant and very exceptional individuals.

In the experiments as reported there is one instance where typhoid bacilli were found in a single case on the tenth day.

The singularity of this finding and its isolation from all the other results that were obtained in the course of examination of a large number of sacks, over a long period of time, in my opinion demands a special examination.

The sudden appearance of three colonies in the sack after an interval of eight days, during which no typhoid bacilli were found, although a large number of colonies were examined, points to some unusual occurrence. The most reasonable explanation seems to me to be that at the time when the contents of the sack were heavily infected with typhoid bacilli, during the process of tilting and agitation previously referred to, some concrete particle in the sewage to which typhoid bacteria were adhering was deposited, and became

dried upon the walls of the sack above the water line. Under these conditions it is my opinion that the typhoid bacillus might remain alive for some time.

Such a dried particle, containing living typhoid bacilli, might conceivably be washed off from the place where it had lodged. These typhoid bacilli suddenly introduced into the sack after an interval of ten days might appear on the plate and be found, as in this case. It is certainly difficult to account otherwise for the sudden appearance of three colonies and for their occurring only on one plate. If these typhoid bacilli had remained alive in the water of the sack throughout this whole period it would be expected that between the second day and the tenth day other resistant individual germs, straggling survivors of the great multitude originally introduced, would also have appeared on some plates and been picked off and identified.

I am inclined to believe, therefore, that this isolated case was due to an accident occurring under the conditions in which the experiment was conducted, and does not indicate that typhoid
6240 bacilli would survive as long as ten days in the water of the drainage canal itself. The outcome of all the other experiments made it distinctly opposite to the latter view.

Answering your question, then, as to the significance of the whole experiment, I would say that in my opinion it indicates a longevity of the typhoid bacillus in the polluted water of the drainage canal of not more than three or four days.

Q. Does the experiment shed any light upon the longevity of the typhoid bacillus in the sediment of polluted streams?

A. I think it does in this way, that although some sedimentation of the suspended matter occurs in these sacs, the tilting and agitating of these sacks each time before the sample was taken led to a thorough mixing of the suspended and sedimented particles, I found no reason for believing that bacilli lived any longer in the sediment of such sacs than freely suspended in the fluid.

Q. What is the behavior of the colon bacillus in soil as compared with its behavior in water?

A. In my opinion it can live longer in soil than in water, but there is evidence that a certain destruction of colon bacilli takes place also in the soil, although not so rapidly as in water.

Q. Is there such a thing as self-purification of soil?

A. Yes. I have here a paper entitled "Self Purification of Made Soil, published by Dr. William G. Savage, Bacteriologist, to the Cardiff and County Public Health Laboratory, and late lecturer on bacteriology, University College, Cardiff."

This paper was published in the Journal of the Sanitary Institute, Volume 24, Part 3, 1903, page 442.

In this paper the writer described the experiments made on the continuance of vitality of the colon bacillus in made soils of various kinds. He finds that the colon bacillus lives for some time in the soil, but disappears as times goes on, the ordinary soil organisms invading the material and taking the place of the colon bacillus. He concludes, "that the gradual diminution and disappearance of the B. coli in this refuse is of interest from the point of view of specific contamination. This organism, apparently, rapidly dies out in such material. It is a more resistant organism than the typhoid bacillus. It is a fair assumption from this that the typhoid bacillus, if present in such soils, would also rapidly die out, and that the danger of SPECIFIC typhoid contamination from building on such made soil can be neglected."

These observations show that B. coli introduced into soil disap-
6241-42pears less rapidly, it is true, than in water, but nevertheless shows a tendency to die out.

6241 The Self-Purification of Soil.

Q. Does the experiment which you have introduced in evidence shed any light on the life of the colon bacillus in polluted water?

A. It certainly does. The control experiments I have described show that the colon bacillus dies off in polluted water when imprisoned under natural conditions in parchment sacks. This confirms what has already been noticed regarding the disappearance of B. coli in the running water of the Illinois River, and adds weight to the view that the life of the typhoid bacillus under these conditions is very brief, since the colon bacillus is a much hardier organism than the former.

Q. Does that experiment shed any light on the life of the streptococcus in polluted waters?

A. Yes, the controlling experiments show that the sewage streptococci die out very rapidly.

Q. To what do you attribute the death of the typhoid bacillus in water?

A. I attribute the death of the typhoid bacillus in such unsterilized water as I have examined to the poisonous action of the products of other microbes.

It is a well established fact that the typhoid bacillus dies off more rapidly in unsterilized water, that is the water containing a normal number of microbes than in the same water sterilized, that is containing no other form of micro-organisms.

It is also well established that the products of growth of one microbe are often injurious and detrimental to another microbe.

Q. Why is it that the typhoid bacillus will not live as long in polluted water as in pure water?

A. In my opinion this is because the products of the microbes are present in more concentrated form in the polluted waters than they are in the purer waters. The action of these toxic products in their concentrated form is naturally more intense than where these products are in a diluted condition.

Q. What is your opinion as to whether the typhoid bacillus will live longer in the sediment of a polluted stream than it would in the water of the same stream?

6242 A. It is my opinion that there would be a little material difference.

Difference between conditions that obtain in moist soil and the
6243 sediment of running streams as furnishing a comparison for the life of the typhoid bacillus.

Q. Would the fact that the typhoid bacillus lived several months in moist soil justify the assumption that it would live for the same length of time in the sediment of a river?

6244 A. By no means.

(Reasons given for above answer.)

Observation on typhoid on Lake Geneva, as reported by
6245 Lortet:

I can attach no importance to them (observations in connection with Lake Geneva), so far as shedding any light upon the longevity of the typhoid bacillus in sediment; since even supposing that the identification were correct, there is nothing to indicate how long such bacteria had been present in the sediment of Lake Geneva.

Typhoid fever in the sediment of a running stream, as stated
6246-47 by Mr. Fuller, and based by the Lake Geneva observations with the reasons why they are not comparable.

Mr. Fuller's contention that the longevity of typhoid bacilli in moist soil and rural places furnishes a parallel for their longevity in the sediment of streams discussed.

6747-48 Q. What reasons, if any, have you for supposing that the conditions described in your experiment closely stimulate natural conditions?

A. The bacteria in the parchment sacs are exposed to similar conditions of temperature. They are also exposed to the action of the substances present in the sewage and such substances formed by the multiplication of saprophytic bacteria within the sacs. The dif-

fusion that takes place through the walls of the parchment sacs allows soluble substances to pass through both those inside the sac to pass out and those outside to pass in, where the osmotic conditions are suitable.

These sacs have been tested with solutions of dyes and acid and alkali, and have been found permeable. Thus, if a solution of litmus be placed in a glass vessel and a parchment sac containing dilute acid be suspended in this solution of litmus, the acid will pass through the walls of the parchment sac and will cause the blue color of the litmus to change to red. Conversely, if a litmus solution be placed inside the sac and the sac suspended in the acid solution, the acid will pass through the parchment into the sac, changing the litmus to red color. In either case the interchange of substances between the parchment sac and the fluid outside continues until a state of equilibrium is established. So that the contents of the parchment sac suspended in the water of the drainage canal are free communication with the waters of the drainage canal itself, and interchange of food substances and other toxic substances being possible.

For these reasons it is my judgment that the conditions of the
6249 experiment simulate with great exactness natural conditions.
I should anticipate that typhoid bacilli would live longer in glass bottles than in parchment or celloidin sacs.

6250 It is my opinion that typhoid bacilli could not survive the journey from Chicago to St. Louis coming from the sewers of Chicago, and I do not believe that such typhoid bacilli would arrive in the Mississippi River in a condition that they could be called a menace to the inhabitants of St. Louis. I do not believe that any dangerous elements from the sewage of Chicago reaches as far as the Mississippi River, and if that is the case, I do not see how the
6251 settling basins of St. Louis could protect against the sewage of Chicago.

Q. If none of the sewage in its dangerous state reaches the City of St. Louis from Chicago, from what source, in your opinion, comes the infectious matters which these settling basins eliminate?

A. It comes, in my opinion, from places nearer to St. Louis
6252 than Chicago, places situated on the Missouri, Mississippi and Illinois rivers, within five or six days' flow from the intake tower.

6252 Condition of the water in the settling basin for a period of thirty days.

EPIDEMIOLOGY.

6254-55 Familiarity with epidemics and special epidemics investigated at Ithaca and Butler, Pennsylvania.
6256 Epidemic at Lowell.
6257 Plymouth epidemic.
6258 Hamburg epidemic, Lausen epidemic.

Q. What does the term "epidemiology" embrace?

A. As I understand it, the term epidemiology embraces the study of vital statistics, the interpretation of these statistics; a consideration of the weight to be placed on the data of bacteriology and chemistry; a study of the modes of causation of various forms of infectious diseases; a study of the sources and intensity of infection; a study of the relative incidents of disease upon rural and urban populations and the modes of spread of disease in urban and rural districts; a study of the relative share of urban and rural populations in polluting the public water-courses; a study of the vehicles of infection in any given community, such as food, drink, air, infection, etc.; a study of the character and manner of differentiation of various infectious diseases.

As I understand, these and kindred topics are included within the scope of what is sometimes known as the science of epi-
6259 demiology.

Q. Explain what you mean by interpretation of vital statistics.

A. Assuming that the facts that furnish the basis for a study of vital statistics are accurately collected and tabulated, there remains the very important question of the interpretation of such statistics. It is not a matter of indifference how the figures so collected are viewed by the statisticians. Statistical pitfalls are numerous and certain fallacies of interpretation exist, the introduction of which may vitiate any conclusion drawn from figures in themselves exact.

To give an illustration: It is very commonly assumed that the death rate in a city, that is, the number of deaths per thousand population annually, is a correct measure of the healthfulness of such a city. The death rate, however, among individuals of different ages and of different nationalities varies so much that the crude death rate, that is, the death rate per 1,000 population, without regard to age or sex distribution, or to racial characteristics, is often very far from affording any indication of the healthfulness of a given community.

Thus, that population having in it a large per cent. of infants or of aged individuals would have a larger number of deaths per thou-

sand population than a community having a larger proportion of the individuals between the very resistant ages of say fifteen and forty.

So, in comparing one section of a city with another, the racial distribution of the population, that is to say, the prevalence
6260 of persons of American born or German or Irish or Russian parentage, will affect the death rate very profoundly. In the interpretation of vital statistics, therefore, the interpretation of the crude fact observed, is a matter of the utmost interest.

Manner in which racial characteristics manifest themselves in the vital statistics.

6261 Q. What do you understand to be a proper interpretation of vital statistics?

A. An interpretation taking into account all of the known factors of every kind that may have had a share in bringing about the conditions observed; unless these factors are considered there can be no such thing as proper interpretation.

Mortality percentage method and its disfavor among sanitarians and epidemiologists here and in Europe fully discussed.

6261–6263 Q. Does the mortality percentage method receive your approval as a sanitarian and epidemiologist? ?

A. For the reasons already considered, I do not regard this method as shedding a true and proper light upon the relative
6263–64 incidents of disease in a community. The fallacious character of this method fully set forth by illustration.

Professor Sedgwick's statement that the mortality percentage method is regarded as on the whole the most accurate, dis-
6265–66 cussed in full.

Value of chemical and bacterial analyses of a water-course and
6267 the assistance to a sanitarian furnished by chemistry and bacteriology in arriving at a correct judgment.

Chemical and bacterial analyses sheds light on the problem of self-purification of streams.

6267 Q. How is the presence of infectious disease ascertained?

A. In nearly all countries there are regulations requiring physicians to report all cases of certain infectious diseases occurring in their practice to the health authorities. Some infectious diseases, such as smallpox, are very fully reported in this way, but it is true of many of the infectious diseases, especially the less highly contagious kinds, that such reports to the health authorities are not made uniformly by all physicians.

In most parts of the United States the system of notification of cases of infectious diseases is very imperfect and incomplete. It is

perhaps, rather the rule than the exception for cases of infectious diseases to be reported promptly and in their full numbers to the health authorities. In too many instances all that the epidemiologists in this country have to depend upon is the mortality returns, the number of deaths recorded by the health authorities rather than the number of cases reported to them. Usually the only clue to the
6268 prevalence of typhoid fever in a community during a given period is the number of deaths recorded in the official health reports.

Q. What are the ordinary modes of causation of infectious diseases?

A. The ordinary modes of causation are very different and variable, according to the specific infections. In some cases there is reason for thinking that the infectious matter is air borne, such, for example, as in the case in tuberculosis, and probably in smallpox. In others, that the infection is transmitted from one individual to another by more or less direct contact, as is the case in diphtheria. In still other cases the use of infected drinking water or infected food is the common mode of causation.

Q. What are the chief sources of infection in typhoid fever?

A. The typhoid fever germ usually leaves the body of a patient in the urine or feces. These substances may carry the infection to the sewers, in case proper methods of disinfection are not practiced. The mingling of such infected sewage, containing the discharges from the bodies of typhoid fever patients, with water that is soon afterwards used for drinking purposes, is the most common source of infection in typhoid fever, by far the largest number of outbreaks of typhoid fever that have been traced being due to infected drinking water. A considerable number of cases and of epidemics of typhoid fever are, however, caused in other ways. The milk supply sometimes becomes infected, either directly from a typhoid fever patient or convalescent, or indirectly through the medium of infected water.

Articles of food that are eaten in a raw condition, such as oysters, celery and certain fruits, may also be the source of infection in this disease.

It may, also, sometimes happen that the dust from dried excreta may be blown about and settle upon food and thus be taken into the alimentary tract.

Insects, too, may play a part in contaminating substances. In the case of physicians and attendants having to do with the treatment of a typhoid fever patient, infection by contact may also occur, and in houses in which there are typhoid fever patients or convalescents

what is known as a secondary infection sometimes results, these cases of secondary infection being due to more or less direct transfer
6269 of the discharges of the patient to well persons.

An increase of typhoid fever in a city may be due, of course, to an increased infection of the public water supply, but it may also be due to an infection of the milk supply or to an infection
6269 of private wells, to special opportunities for the transmission of disease by insects.

Assuming that the reports of the St. Louis Board of Health show an apparent increase in typhoid fever during the years 1900-1-2 and 3, as compared with previous years, it is not, in my opinion, a justifiable conclusion that said apparent increase of typhoid in St. Louis is due to any infectious matter passing through the sewers of Chicago and thence into the Illinois and Mississippi rivers by way of the Drainage Canal. An increase in the infection of the Mississippi River water from points near at hand would seem to me to afford a more satisfactory and scientific explanation of an increase of typhoid fever
6270 in St. Louis than the passage of any typhoid bacilli into the intake of the St. Louis water-works from a point so far removed as Chicago.

At the time of the Spanish-American War in this country outbreaks of typhoid fever among the soldiers in the military
6271 camp were traced to infection by flies.

Dr. Alice Hamilton's demonstration in the Nineteenth Ward.
6271–72 Intensity of infection.

Evidence that the nearer the source of infection the more
6272–73 severe the incident of disease.

Decrease in virulence of a typhoid fever germ.
6273 The relative virulence of a typhoid bacillus coming from a remote as compared with a nearer source.
6274 The effect of an urban and rural population upon a water shed distinguished.

Q. Is typhoid fever more permanent in urban than in rural communities?

A. No, sir; just the reverse is true. Tyhpoid fever is a rural
6274 rather than an urban disease.

(A discussion of the subject follows.)

The importance of rural population as considered by an epidemiologist.

Professor Sergwick's position on rural and urban population disclosed.
6275–76 Q. Do you know of any important typhoid epidemic in which infection has come from the rural population?

A. The most extensive localized epidemics of typhoid fever in this country, namely, those at Plymouth, Pennsylvania; Ithaca, New York, and Butler, Pennsylvania, have been caused by infection from a rural population. Lowell, Massachusetts, was due to infection of the Merrimac River by isolated cases of typhoid fever.

Q. Are there any reasons why infection from the rural population is to be specially feared?

A. It seems to me that there are at least two reasons why the infection of a water-course by rural population is specially to be feared.

Q. What are those reasons?

A. The first of these is that, on the whole, disinfection of the dejecta and urine is less carefully and thoroughly carried out in rural communities than in urban, so that in a given number of cases of typhoid fever a larger proportion will be improperly cared for in rural communities than in cities.

In the second place, the storing up or accumulation of infectious material from typhoid cases may result in a very heavy infection of a water-course, since the discharges that have collected during the whole course of a case of typhoid fever may be washed, all at once, by a heavy rain into a water-course.

Still another reason, and one that I believe to be very important, is that when typhoid bacilli are added to a stream in the sewage of an urban community, they are accompanied by a large amount of organic matter and a large number of saprophytic bacteria.

In rural infection, on the other hand, the bacilli from a single case of typhoid fever may pass into a stream unaccompanied by any considerable amount of organic matter. The dilution with pure water of this relatively large number of bacilli and their mingling with the waters of a large stream constitute a peculiarly dangerous kind of infection. The competition of the sewage bacteria in such a case is not nearly so great as in the case of typhoid bacilli passing into the sewers of a large city.

It has been shown previously that typhoid bacilli will live longer in relatively pure water, in the presence of a relatively small amount of organic matter, than in a polluted water, charged with the sewage of a great city.

For these reasons, therefore, it is my judgment that the infec-
6277 tion from a rural population should not only not be ignored, but should be especially feared.

Q. What do you mean by character of disease as an element to be considered by sanitarians and epidemiologists?

A. I mean by that that the vital statistics, the reports of morbidity and mortality, should be examined with a view to determining the class and nature of the disease as disclosed by an analysis of the alleged causes of death as reported in the official publications. The discrepancies in nomenclature and the varying practice of the custodians of public health records in the various parts of the coun-
6278 try render such examination necessary if a correct idea is to be obtained regarding the actual character of the disease present or rife in a given community.

Tables of typhoid fever deaths in St. Louis by the month from
6279 1890 to 1903.

Table of typhoid fever deaths in Chicago by the month from
6280 1890 to 1903.

Q. What relation do the monthly deaths from typhoid in Chicago bear to those in the City of St. Louis during the period from 1890 to 1903, inclusive?

A. From these tables I am unable to discover any relation
6281 between the monthly deaths from typhoid fever in Chicago and those in St. Louis.

(A further comparison follows.)

Q. Is an increase in the death rate from typhoid fever in St. Louis preceded by a corresponding increase from typhoid fever in Chicago?

A. It is not.

Q. Is a decrease in the death rate from typhoid fever in Chicago followed by a decrease in the death rate from typhoid
6281 fever in St. Louis?

A. I am unable to discover any relation between the monthly deaths from typhoid fever in Chicago and those in St. Louis.

A decrease in the number in Chicago is not followed by a decrease in the number in St. Louis, nor is an increase in the deaths in St. Louis preceded by a corresponding increase in the deaths in Chicago.

Q. If the typhoid fever in St. Louis for the period from 1890 to 1903, inclusive, was caused by infection coming from the City of Chicago, would not some relation exist between typhoid conditions in Chicago and the typhoid conditions in St. Louis?

A. I should certainly expect to find some relation obtaining between the prevalence of this disease in Chicago and that in St. Louis. I should anticipate that in general if the typhoid fever conditions in St. Louis were dependent upon those in Chicago that a large number of deaths from typhoid fever in the latter city would be followed

within three or four months by an increase in the number of typhoid deaths in St. Louis.

No such relation appears in the monthly records of typhoid fever of these two cities as tabulated.

6282 It is, therefore, my judgment that typhoid fever conditions in St. Louis are unaffected by a large amount or a small amount of typhoid fever in Chicago.

Flood water in the Illinois River and its relation to the increase

6282–83 or decrease of typhoid fever deaths in the City of St. Louis fully discussed, showing no relationship existing.

In the four years for which record is at hand, absolutely no relation exists between low water of the Illinois River, as shown

6283 in the gauge readings at Kampsville, and an increase or decrease in the typhoid mortality in the City of St. Louis.

Effect of cold weather in Chicago with high typhoids manifest no results in St. Louis after allowing for the period of incuba-

6284 tion and distance of flow.

From an examination of the monthly deaths recorded from typhoid fever in Chicago and St. Louis, between 1890 and 1903, inclusive, I am unable to discover any dependence of the mortality in St. Louis upon that in Chicago as repects extent of mortality, seasons of the year or stages of water in the Illinois River.

GERM DISEASES.

A protozoan is a one-cell animal; a bacterium a one-cell plant.

I have examined the organisms of typhoid and malarial fever and have made blood examinations from cases of typhoid fever and malaria and have examined the literature with reference to the geographical distribution, pathology and general character of these

6285 diseases. The proper diagnosis of disease has become a very important question in the last few years, and the most important means of distinguishing between typhoid fever and malaria, and it is by examinations made in the laboratory.

Typhoid fever, malarial fever, intermittent fever, remittent fever, typho-malaria, congestive and their clinical diagnoses.

6286–88 Most of the infections designated by these different names are either typhoid fever or malaria, and these terms mentioned in your question are not generally employed at the present time as representing different and specific types of diseases. It is generally considered that these designations relate in almost every instance to cases of typhoid fever and that they should be so regarded. It is the

general opinion among statisticians that the deaths so classed
6288 should be transferred bodily to the column of deaths from typhoid fever, since they are practically in all cases deaths from typhoid fever and not deaths from malaria. Malaria, in fact, as it occurs in temperate countries is rarely fatal.

Professor William Osler, of the Johns Hopkins University, in his article on malaria fever in Allbutt's System of Medicine, Vol. III, p. 738, states:

"Unfortunately, for many years and in many regions practitioners have been in the habit of labeling as malaria every instance of obscure disease in which they could not make a diagnosis, so that the vital statistics are falsified in a remarkable manner. In the United States Census Report for 1890, which covers the six preceding years, the deaths from malarial fever in New York and in Brooklyn were more numerous than from typhoid fever. In both these cities it is notorious that a death from true malaria is a great rarity, not more than three or four cases occurring each year in the entire hospital practice of the City of New York.

In the regular forms of malarial fever the death rate is very slight, and results usually from complications, such as acute nephritis."

In the testimony of Dr. William C. Woodward, who has already testified in this case, page 4602, I find the question:

"In this table marked Exhibit 74 you have what is known as typhoid malaria and typhoid fever. What is the difference between typhoid fever and typhoid malaria?" The answer: "I regard a case of typho-malarial fever as a case of typhoid fever, in which the physician has made a mistake at the beginning and called it malarial fever, and he seeks the best way out of the hole. We classify them separately, because some people regard them as different diseases, and we furnish our statistics to people and let them use them as they see fit, but I have expressed my opinion."

There is a very marked distinction between malarial fever and the other diseases, unless you regard the typho-malarial as typhoid fever. When it comes to typhoid malaria and typhoid fever, the best authorities to-day, I believe, regard them as the same disease."

In a recent article by Dr. John S. Fulton, Health Officer of Baltimore, Maryland, entitled "Typhoid Fever" and appearing in the Journal of the American Medical Association for January 9, 1904, this matter of the relation between typhoid fever and malaria is exhaustively discussed with a very full statistical presentation. On page 74 of this article is given a series of charts, showing the typhoid mortality in different sections of the United States. These charts show

that the malaria curve below the line reflects the typhoid curve above as faithfully as the shores are reflected by the surface of a lake, the seasonal apex of the groups corresponding.

Dr. Fulton states his own opinion as follows:

"My personal belief is that fatal malaria intoxication does not happen to one citizen a year in Maryland, though malaria is in some parts of the state a considerable cause of disabiliity."

Then again: "Of all the mortality charged in the South to malaria, death perhaps is due to typhoid fever. The United States Army experience would indicate that not more than half is due in fact to typhoid, and certainly more than fifty per cent. of the mortality so charged is not due to malaria. In the North a much larger part, probably two-thirds of the reputed malarial mortality, represents unrecognized typhoid."

Outside of certain well-known areas malaria does not kill citizens of the United States, and within these areas, where malaria is a cause of grave sickness, its right to be considered an important cause of death has not been subjected to the rigid scrutiny which its apparent importance demands."

"Speaking for that part of the United States that I know best, I can say that the terms 'malarial' and 'typho-malarial' express no definite belief as to the cause or character of a disease, but are applied to fevers of indeterminate nature." It is my opinion that these statements represent correctly the prevailing judgment regarding these designations of intermittent fever, etc., used in mortality records. The great majority of the deaths so reported are due to typhoid fever.

6289–90

The number of deaths reported as from typhoid in the City of St. Louis for the period of 1890 to 1903 do not represent the total typhoids. My reason for this is that I find in the record of the Health Department of St. Louis a considerable number of deaths under the heading "remittent, intermittent, typho-malaria, congestive and simple continued fevers." Since there is, in my opinion, no question that a number of deaths reported under these heads were undoubtedly deaths from typhoid fever, it is certainly difficult, if not impossible, to determine how many typhoid fever deaths actually occurred in St. Louis during a given period. Since there is no reason to suppose that these figures do not correctly represent the reports received from the physicians of St. Louis, I see no escape from the conclusion that the value of these statistics to properly disclose the number of typhoid fever deaths occurring in St. Louis was due to an improper diagnosis. These terms have the weight of traditional use

behind them. Furthermore, it is only in recent years that the sure distinction and differentiation of typhoid and malarial fevers has become possible through laboratory methods. Physicians educated before the laboratory methods were in vogue do not habitually employ such methods, and without these methods, on the basis of clin-
6291–92 ical symptoms alone, it is often difficult and well nigh impossible to differentiate obscure and difficult types of fever.

In my opinion, no city in the United States has as large a death rate from genuine malaria as would be indicated by the official records of St. Louis, assuming that all deaths reported under the heading of remittent, intermittent fevers, etc., were deaths from malaria. The City of Baltimore, where particular attention has been paid to malaria, shows the relatively small number of deaths reported from malaria and typhoid malaria fevers. It is generally recognized that this
6292 classification is an improper classification from a scientific standpoint as affording a true indication of the prevalence of typhoid fever and malaria.

Table of typhoid and malaria, etc., for St. Louis from 1895
6293–94 to 1903.

Q. Will you state what this table shows?

A. This table shows the deaths in St. Louis by months from January, 1895, to December, 1903, inclusive, recorded under the headings A typhoid fever, B remittent, intermittent, typho-malarial, congestive and simple continued fevers.

This table shows a close parallel between the number of deaths reported from these two causes. In the months of July, August, September and October the number of deaths reported under both of these headings is high, while in the months of April and May it is, on the whole, low.

An interesting change is noted in the latter part of this table. For the first five years of the table the number of deaths under the heading B (remittent fever, etc.) was greater than the number of deaths under the heading A (typhoid fever). Beginning with 1901, the reverse is true. The number of deaths reported under the heading typhoid fever becomes greater than the number reported under the heading remittent fever. To take, for example, the month of September:

	A (Typhoid Fever).	B (Remittent Fever).
1895	9	32
1896	13	27
1897	17	31
1898	14	18
1899	16	28
1900	13	20
1901	24	9
1902	21	16
1903	42	17

Inspection of these figures shows that in the last four years there has been a transfer from the column B, that of remittent fever, etc., to the column A, that of typhoid fever, the effect being to diminish the number of deaths reported as remittent fever, etc., and to
6296 increase those reported as typhoid fever.

Table of typhoid deaths, remittent deaths, etc., and the added
6296 totals for the City of St. Louis from 1890 to 1903.

Q. State what the table you have just read in evidence shows.

A. This table shows a similar condition to that evidenced in the table of monthly tables just produced. The total number of deaths per year reported under the heading typhoid fever, and under the heading remittent fever, etc., are given in this table.

They show that a much larger proportion of deaths is recorded under the heading remittent fever, etc., before the year 1900 than since that year.

They also show that, whereas the number of deaths reported from typhoid fever was generally less during the first ten years of this period than the number of deaths reported from remittent fever, etc., during the last four years, the case has been just reversed. It is evident that there has been some cause or that there have been some causes at work tending to produce a more accurate diagnosis
6296 on the part of physicians, and that a larger number of cases of true typhoid fever have been recognized as such during the latter period than during the earlier one.

It certainly seems reasonable to suppose that such a letter (sworn to by Dr. Teichmann) as that described in your question as having been sent to the physicians of St. Louis would have some effect upon their scrutiny of cases of fever and that it might cause them to pay closer attention to diagnosis and perhaps apply some of the modern

methods of differentiating typhoid fever from conditions for
6297 which it might be mistaken. It is certainly, in my opinion, a significant fact that since 1900 there has been this decided change in the mode of reporting deaths.

Beginning with the year 1900, the proportion of deaths from typhoid fever is much greater as compared with the deaths from intermittent fever than in the preceding decade. This is just the effect that would be expected if the attention of the physicians had been specially directed to the diagnosis and differentiation of typhoid fever in its various forms. For the three years, '99 to 1901, the total number of deaths reported from typhoid and remittent fever, etc., is almost entirely the same, almost precisely the same, but the proportion reported from typhoid fever alone in 1900 and 1901 is much greater than in 1899. It is my opinion that, considering the number of deaths reported separately under the heading typhoid fever, that the total number of such deaths and the average number is not correctly represented by the tables reported under this head alone. There is every reason to supopse that during the first five years covered by these tables a larger proportion of the deaths recorded under the heading intermittent fever, etc., were genuine typhoid fever than in the latter period, owing chiefly to the progress that has been made in the method of diagnosis. One way of attempting to arrive at the true typhoid mortality in the City of St. Louis during the period indicated would be by assuming that all the deaths recorded under the heading remittent fever were actual cases of typhoid fever and should be added to those is the column of typhoid fever proper. Another method would be to assume that a certain proportion of the deaths reported, say fifty per cent., were deaths from typhoid and that this fifty per cent. should be added to the deaths reported under the heading typhoid fever alone. The truth lies somewhere between these two extremes. The proportions undoubtedly vary from year to year.

On the whole, it is my opinion that most epidemiologists and sanitarians would consider that a nearer conception of typhoid fever mortality in St. Louis would be derived by transferring all the
6299 deaths from the remittent column than by transferring only fifty per cent: of the deaths, but that is a matter of opinion simply.

Table of deaths reported from malaria fever, etc., in Chicago
6300 from 1851 to 1902.

I have examined the malaria deaths for Albany, Baltimore, Maryland, and there is the same general correspondence by months and years that has been noted in the St. Louis records. The large

number of malarial deaths reported in Chicago was in the year 1891, the same year when typhoid fever prevailed in epidemic form in this city. In general when the deaths reported from typhoid fever are low those reported from malarial fever are low, and vice versa. A very interesting condition is revealed by the mortality report from typhoid fever and malarial diseases in the City of Albany, New York. As is well known, a sand filter was put in operation in Albany on September 6, 1899. During the ten years, 1891 to 1899, inclusive, the total number of deaths reported from typhoid fever was 1,777, or an annual average of 26, since the filter was opened, as against 86 preceding.

An exactly similar decline is noticed in the number of deaths from malarial diseases. Prior to the opening of the filter the deaths reported from malarial fever amounted to 61, an annual average of 7. In the four years since the filter was opened only two deaths in all have been reported from malarial disease, or an annual average of one-half. The inference is plain that both reported causes of death, namely, typhoid fever and malarial diseases, have been affected by the opening of the filter, and the only conclusion that can be drawn is that the deaths as reported from malarial diseases were really cases of genuine typhoid fever.

6302 The strict parallelism between the deaths reported from typhoid fever and malarial fever in St. Louis and in Chicago, in Baltimore and in Albany, demonstrates conclusively to my mind that the confusion in diagnosis already set forth has existed in widely separated localities.

Table of typhoid fever deaths in St. Louis, based upon population; typhoid alone; typhoid plus fifty per cent. of recorded
6304 deaths under intermittent, etc., and typhoid plus all the deaths the heading intermittent, etc., and the increase of population, based on Farr's formula.

Q. Please state what these tables show as to the death rate in the City of St. Louis from 1890 to 1903, based upon the percentage of population.

A. They show a considerable difference in the death rate, according to the number of deaths assumed to be deaths from genuine typhoid fever. Considerable variation is exhibited in the three
6304–05 columns during this period, owing to the transfer of reported deaths from the intermittent column to the typhoid column, as already referred to several times in my testimony.

Q. Will you compare the death rate of typhoid fever in St. Louis from 1890 to 1899, inclusive, with that of 1900 to 1903, inclusive?

A. Assuming that the deaths reported under the heading typhoid fever alone during this period were the only deaths that occurred from this disease in the City of St. Louis, the average annual death rate from 1890 to 1899, inclusive, as shown in the detailed table, excluding, however, the year 1892, as being a year of special epidemic prevalence, was 28.8. On the same basis the average annual death rate from 1900 to 1903, inclusive, was 36.5.

Assuming that only one-half of the deaths recorded under the heading intermittent fever, etc., were deaths from genuine typhoid fever, the average annual death rate from 1890 to 1899, inclusive, excluding as above the year 1892, was 46.07. On the same basis the average annual death rate from 1900 to 1903, inclusive, was 44.67.

Assuming that all the deaths reported under the heading intermittent fever, etc., were deaths from genuine typhoid fever, an assumption which, in my opinion, is not very wide of the mark, the average annual death rate from 1890 to 1899, inclusive, excluding as above the year 1892, was 65.4.

On the same basis that from 1900 to 1903, inclusive, was 52.1.

On either of the latter assumptions the death rate from typhoid fever in the four years, 1900 to 1903, was distinctly lower than in the preceding decade, even when the year of maximum typhoid prevalence in that decade is excluded from the estimation.

Q. Assuming that all the deaths in the typhoid column and the typho-malarial column are typhoid, how does the period four years prior to 1900 compare with the period four years since 1900, as to whether there is an increase or decrease in the typhoid fever in the City of St. Louis?

A. The annual death rate on this basis is almost exactly the same, being 52.2 for the period of four years prior to the opening of the canal and being 52.7 for the period of four years since the opening of the canal. With these figures it would be impossible to assert that there has been either an increase or a diminution in the typhoid fever death rate in this period on the assumption just predicated.

Q. Has typhoid fever increased or decreased in the City of St. Louis since 1900 over the conditions that obtained for the ten years prior to 1900 in the City of St. Louis?

6305–06 A. It is emphatically my opinion that the average death rate from typhoid fever in the City of St. Louis has been less in the four years beginning with 1900 than the average for the preceding decade, excluding in this comparison the epidemic year of 1892.

A comparison of the typhoid death rate in St. Louis with those
6306 in other American cities during this period.

The reasons given why the typhoid fever death rates in St.
6307 Louis are higher than those indicated by the figures recorded under the heading "typhoid alone."

In considering all the facts regarding the mortality of typhoid fever in the City of St. Louis during the period indicated that can be obtained from the official records as published, it is my opinion that the average annual death rate from typhoid fever in that city has been lower for the four years, 1900 to 1903, than for the preceding decade, excluding the epidemic year of 1892.

From the facts already cited and all the information that I have, I conclude that there has been no increase in the annual death rate from typhoid fever in the City of St. Louis since January 17th,
6308 1900, as compared with the average annual death rate for the four years preceding 1900.

It is my best judgment, based upon all the information of which I have become possessed, that no portion of the typhoid mor-
6308 tality occurring in St. Louis since January, 1900, can be attributed directly or indirectly to the opening of the Chicago Drainage Canal.

Running water purifies itself from pathogenic bacteria that
6310 have been placed therein.

Condition of the Mississippi River west of the center thread of the main channel below the mouth of the Illinois River down to the intake tower, as to its value for drinking purposes and its
6310 liability to carry water-borne diseases now than before the Drainage Canal was opened, as testified to by Professor Sedgwick and commented on by Professor Jordan.

The following questions put to Professor Sedgwick were put
6310 to Professor Jordan for his consideration:

The increased speed of the current as affecting sedimentation
6311 in the Illinois River.

The increased speed of the current as affecting the sewage from Joliet and Peoria and other towns being removed to the Mississippi River, as compared with conditions prior to the opening of the Drainage Canal.

Clearness and turbidity of the water since the opening of the
6312 canal and its effect upon sedimentation of bacilli, as compared with previous conditions of greater turbidity.

The effect of an increased current in the Illinois River upon the

typhoid diseases being manifest to the inhabitants of the State
6313–14 of Missouri.

The effect on typhoid fever in sewage-polluted waters.

The presence of coli bacilli at Grafton and its effect upon the sanitary quality of the water.

6315 Typhoid in Chicago being deposited in Lake Peoria and flushed out by freshets.

Effect of such deposits of typhoid in Lake Peoria when scoured out by freshets being in greater amount than the number at
6316 the bear trap dam at any time.

It is my opinion that typhoid fever germs coming from Chicago sewage rarely, if ever, live long enough to reach Averyville, and it is consequently my judgment that such germs cannot be deposited in large numbers in the lakes and slack water portions of the Illinois River water above Peoria.

It is emphatically my opinion that the number of typhoid germs in the water of the Illinois River and Lake Peoria is never as
6317 great as the number in the Drainage Canal near the bear trap dam at Lockport, and there is no evidence to bear out a counter opinion.

There is no evidence that typhoid bacteria accumulate in basins
6318 of the river, and remain in storage.

DETROIT EPIDEMIC.

I have read the testimony that has been given in this case regarding the dredging of the Black River at Port Huron and its supposed connection with the outbreak of typhoid fever in Detroit. As an epidemiologist, I do not consider the fact established beyond a reasonable doubt, for the reason that other sources of infection have not been eliminated; and, moreover, it is my opinion, as a bacteriologist and epidemiologist, that under the conditions as described typhoid bacilli could not travel from the Black River at Port Huron to Detroit in sufficient numbers and in a sufficiently virulent condition so that they would be capable of causing an outbreak of typhoid fever in the latter place.

If the only pollution of the Illinois River was that coming from Chicago, the dilution, sedimentation and the time interval between Chicago and Grafton would be factors of sufficient power to render the water of the Illinois River as it emptied into the Mississippi free from all liability of introducing typhoid fever or any other water-borne disease into the Mississippi.

From all the knowledge that I have, I have formed the opinion that the water of the Illinois River at Grafton does not contain infectious elements derived from the sewage of Chicago, and that consequently such water reaching the Mississippi River and becoming mixed with that water is not a menace to the health of the inhabitants of the State of Missouri or the citizens of St. Louis. I know of no evidence that indicates directly or indirectly that the waters of the Illinois River at Grafton are infected from the sewers of Chicago, and in view of the large amount of pollution of the Illinois River that takes place at points less remote from its mouth than Chicago,
6320 it is my opinion that convincing evidence of such infection coming from Chicago would be very difficult if not impossible to secure.

I do not believe that infections or dangerous matters passing into the sewers of Chicago find their way under existing conditions into the water supply of the City of St. Louis, for the reasons which I have set forth previously in great detail. Assuming that there was no other source of infection above the intake except Chicago, I cer-
6321 tainly do not believe that typhoid fever germs from Chicago would be liable to find their way under existing conditions into the water supply of St. Louis.

I have myself made a number of analyses, experiments and observations upon the waters of the Drainage Canal, the Illinois and Mississippi rivers and have examined with some care report of analyses, reports and observations made by others, and I have been unable to discover any evidence that justifies the assumption
5323 that typhoid germs can or do pass from Chicago out of the Illinois River into the Mississippi River, thence to the Chain of Rocks and the intake tower of St. Louis.

ASIATIC CHOLERA DISCUSSED.

6327 The increase of typhoid in St. Louis, as attributed by Professor Sedgwick beyond a reasonable doubt to the Chicago Drainage Canal, is discussed by Professor Jordan negatively, and he gives the following reasons:

Assuming that there had actually been a marked increase of typhoid in St. Louis since the opening of the Drainage Canal, which appears to me to be contrary to the fact, it would, in my opinion, be more reasonable and significant to attribute such an increase of typhoid fever to other causes, such, for example, as an infec-
6323 tion of a water supply near the water intake, to infection of the milk supply or to some other factor rather than to infected sewage coming from the Sanitary District of Chicago.

The water of the Illinois River at its mouth is no more unsafe and unwholesome now than it was before the opening of the canal, and consequently the Illinois River water has not rendered less safe and wholesome the water of the Mississippi below the mouth of the Illinois. It is my best judgment that the inhabitants of the Missouri using the waters of the Mississippi below the mouth of the Illinois for drinking purposes, are not under existing conditions liable to contract typhoid fever by reason of sewage from the Chicago Drainage Canal. In reply to Professor Sedgwick's statement that the mere presence of pollution (I mean by that disinfected sewage), that is, supposing Chicago reduced her typhoid rate and could still put her sewage down there, that sewage, as affecting the longevity or growth of germs which go in from Peoria or anywhere else, would be an added menace to cities with water supplies even if she did not send typhoid germs down; sending the filth alone down is serious," is answered by Professor Jordan as follows:

"On the contrary, it is my opinion that the introduction of sewage or organic matter of a similar character into the river water is distinctly detrimental to continued longevity or growth on the part of the typhoid fever bacillus. In my judgment, the experiments carried out upon the life of the typhoid fever bacillus in the waters of the Drainage Canal show that the presence of a considerable amount of organic matter or sewage in the water favors the speedy dying out of typhoid bacilli, rather than their continued vitality. As I have already pointed out, this is what might be anticipated in view of the greater concentration of the toxic products of saprophytic microbes in waters highly charged with organic matter than in purer waters.

This being the case, it would follow that typhoid fever germs passing into the river from Peoria would not be favored in any
6325 respect by the fact that Chicago sewage had entered the Illinois Valley 150 miles above. On the other hand, they might be actually injured by the products originating from the decomposition of such sewage which carried down even as far as Peoria."

6327 The sanitary character of the water supply of St. Louis prior to 1900 was not a satisfactory one.

6328–29 Bacteriology and chemistry and their positions in sanitary science and water analyses.

Q. From the tables and analyses submitted by you in evidence in this case where is the locality along the Illinois River where practical purification of the sewage of Chicago has taken place

A. Assuming by practical purification is meant the death of typhoid bacilli, in my opinion this purification has occurred before the

flow of the Illinois River reaches Averyville. The exact point must vary somewhat with greater flow, temperature, number of bacilli introduced, concentration of sewage, etc.

6330 SELF-PURIFICATION OF STREAMS AND LEADING AUTHORITIES ON THE SUBJECT.

6331 Typhoid fever bacilli remaining alive sixty days.

From a long and searching examination of all data, chemical and epidemiological, from every source that I have been able to secure, I am convinced that the citizens of the City of St. Louis and inhabitants of the State of Missouri are not menaced or endangered by infectious materials passing into the sewers of Chicago and thence into the Drainage Canal.

Comparing the Missouri River near its mouth with the Illinois River above Grafton and the Mississippi River above Grafton, I have no hesitation in saying that I regard the waters of the Mississippi and Illinois at the point indicated less dangerous and less unwholesome than the waters of the Missouri River. Between the Illinois and the Mississippi rivers at the point indicated there is, in my opinion, not much to choose, from a sanitary point of view. Such an adequate mixture as occurred of the Illinois River water with the Missouri River water would tend to improve the quality of the water, since the number of coli bacilli in the water of the Missouri River are distinctly greater than those in the water of the Illinois, and this condition, in my opinion, indicates that the Missouri River water, which is more highly charged with this objectionable bacteria, is more likely to be the vehicle of typhoid fever bacilli than the water of the Illinois, which does not contain so many bacteria of this type. The mixing of the Illinois with the Mississippi and Missouri rivers, in my opinion, does not create any added danger to the already polluted and contaminated waters of the Mississippi and Missouri rivers below Grafton.

All the analytical data that I have obtained myself and all that I have seen which has been obtained by other investigators indicate, both from the chemical changes that take place and in the diminution of ordinary sewage bacteria, and especially in the diminution of bacilli coli communis, that under existing conditions infectious
6333 material introduced into the sewage of Chicago cannot and do not pass down the Illinois River as far as Grafton, and that none of these substances in a dangerous state reach the intake of St. Louis.

6334 The Washington epidemic compared with the condition of typhoid in St. Louis.

6337 The effect of high water in the Illinois River manifests itself in overflowed banks upon sedimentation.

6338 The effect of the five dams in the Illinois River.

The effect of the removal of the dams in the Illinois River.

6339 In my opinion, the Mississippi River water prior to 1900 at the intake tower of the St. Louis water-works at the Chain of Rocks was unfit and unsafe for drinking purposes during the period mentioned.

Q. If the typhoid condition in St. Louis since 1900 cannot be attributed to the sewage from Chicago beyond a reasonable doubt, will you please state what cause, in your opinion, it should be attributed to and give your reasons for such an opinion?

A. Assuming that the amount of typhoid fever occurring in St. Louis during the period mentioned is in excess of what would naturally exist in a city provided with a fairly pure and satisfactory municipal water supply, in my opinion the most rational and scientific explanation of such excess would lie in the infection of the Illinois, Mississippi and Missouri rivers above the intake tower of the St. Louis water-works by communities, rural and urban, within five or six days' flow from the intake tower. Since, in my opinion, the major part of the water supplied to St. Louis during this period was derived from the Missouri River, and inasmuch as it is my opinion the Missouri River is more seriously infected than either of the other rivers

6342 mentioned, it is my judgment that the infection of the Missouri River has been the main factor in causing such excess of typhoid fever in St. Louis as occurred during the period under consideration.

It is my opinion, assigning due consideration to all of the facts mentioned, that the discharge of the sewage of Chicago into

6342 the Drainage Canal has had no injurious or detrimental effect upon the health of the inhabitants of St. Louis or the State of Missouri.

Summing up all the experience that I have gained in my studies of the Illinois and Mississippi and Missouri rivers and their tributaries, and all the information that I have gained from all sources, it is my firm opinion that no relation near or remote has been traced between the typhoid condition in St. Louis since January 17th, 1900, and the opening of the Drainage Canal on that date; and it is further my opinion that no such relation exists and that the opening of the Drainage Canal was an event entirely unconnected and unrelated with any typhoid fever conditions prevailing in St. Louis at that time, and has remained up to the present time unrelated and unconnected

6343 with the typhoid fever mortality in the City of St. Louis.

CROSS-EXAMINATION,

6344 By Mr. Jeffries.

Case of attempted suicide by swallowing typhoid germs.

6350 Q. Assuming, professor, that the canal mentioned in the preceding question was of sufficient length to permit a flow of six days, and the other facts being assumed in the preceding question, would you consider the water as being free from typhoid

6376 germs?

A. I should not hesitate to consider it as being free from the typhoid bacilli.

Q. Is it not a fact that during the eight days only 7.02 cubic

6392 centimeters of the 700 cc. contained in the parchment sac were developed on table XIII A?

A. I have already pointed out the fallacy of interpretation involved in such a question and any direct answer that could be given to it. The rate and extent of mortality among the typhoid bacilli is the significant thing in these tables rather than the quality of water examined.

I should, however, like to point out that even viewed in the narrow sense in which your question is asked, that this quantity of water, namely, 7.02 cc., contained originally 20,000,000 typhoid bacilli, and that in the course of eight days' examination only three typhoid bacilli were found.

Even when looked at in this way, which seems to me open to misconstruction, it is certainly a highly remarkable and significant fact that out of 20,000,000 bacilli only three should be found,

6392 even assuming what, in my opinion, is not correct, namely, that these three typhoid bacilli had remained alive in the waters

6393 of the sac during this long period of investigation.

I do not regard, however, the general outcome of these experi-

6399 ments or the deductions drawn from them as affected by these accidental occurrences.

Typhoid bacillus swimming.

6405 ERNEST E. IRONS.

DIRECT EXAMINATION,

By Mr. Todd.

I am assistant in the University of Chicago in bacteriology; graduated from the University of Chicago in 1900, and was associated with Professor Jordan in the work of Streams Examination.

Also had charge of the laboratories at Peoria, Grafton and St. Louis, under the direction of Professor Jordan.

I assisted Professor Jordan in conducting the experiment made on the life of the typhoid bacillus in the drainage canal and in the preparation and carrying out of the experiment.

I made an examination of the waters of the Mississippi River at Quincy, Illinois, for the purpose of determining the presence of the bacilli coli communis. This was in the fall of 1902, in September and October, and in December until February, 1903. The method pursued was the same as that in the experiment at St. Louis.

TABLE OF RESULTS.

Comparing the results of my examination at Quincy with those at Grafton in 1901, the coli bacillus was much more numerous in the Mississippi River at Quincy than it is in the Mississippi River at Grafton, or of the Illinois at Grafton.

PROF. F. R. ZEIT.

RE-DIRECT EXAMINATION,

By Mr. Todd.

Since giving my testimony I have made an experiment upon the longevity of the typhoid bacillus in conjunction with Prof. Jordan and Prof. Russel. The plan outlined by Prof. Jordan was that substantially followed by me, and each was to do his respective work at stations selected. I adopted two plans: the first was to use parchment sacs; the second was to use celloidin sacs, both intended to allow osmosis, and both to contain the typhoid bacillus. In the presence of the normal saprophytes present in the water of Lake Michigan and the Chicago River, the parchment and celloidin sacs both allowed osmosis to take place. Parchment sacs of a size to contain 1,000 cc. were prepared, and in the upper end was inserted a glass tube of a size of about 10 mm. The celloidin sacs were prepared from what is known as Park-Davis' Veterinary Capsules No. 00. The parchment and celloidin sacs were thoroughly tested. These sacs were inoculated with typhoid bacilli which had grown upon agar slants for twenty-four hours in an incubator, and enough material was placed in the sacs to produce a mixture of about five hundred thousand typhoid bacilli to the cc. of the water. That was bacillus X from Prof. Jordan and a bacillus we received from Park-Davis & Co. in Detroit. Park-Davis' bacil-

6423 lus had been used to immunize a horse, and we also received the serum of the immune horse.

The sacs were suspended in the Chicago River at the Ashland avenue bridge, and similar sacs were suspended in a jar of water through which fresh Lake Michigan tap water was constantly flowing. The boxes were prepared in the same manner in which Prof. Jordan prepared his. The sacs were seeded with typhoid bacillus after they were first filled with river water, so as to make the sacs a mixture containing between 200,000 and 1,500,000 typhoid bacilli per cc. We used an average suspension of 500,000 typhoid bacilli to the cc. in each sac.

The first samples were taken from the sacs about twenty-four hours after the sacs were placed in the water, and daily after that.

There were eight experiments made at each place. That is,
6425 eight experiments at the Ashland avenue bridge on the river water and eight experiments made in flowing lake water from the tap of the Post-Graduate Laboratory.

Methods employed in differentiating the typhoid fever bacil-
6426 lus from the parchment and celloidin sacs and the application of the Widal test.

6428 Q. Will you state in detail the results that you obtained from all these experiments made by you at Ashland avenue?

A. In all the experiments with a surprising similarity we found that during the first twenty-four hours the total number of bacteria would greatly increase, and typhoid bacilli could be found even with the increasing numbers of all bacteria present in the sac, and that typhoid bacilli were found for the next day, during which the total number of bacteria greatly decreased, and from now on the total number of bacteria continued to decrease, except the typhoid bacilli which were found for three days at the most in the Chicago River water. It was impossible after three days in any particular sac to find typhoid bacilli. There was no difference in the results of the experiments between the parchment sac and the celloidin sac; in both there was great increase of all bacteria for twenty-four hours. Then the number dropped from day to day, and no typhoid bacilli could be found after the third day; in some of the experiments after two days we found no typhoid bacilli. The longest we ever found them was three days. In the parchment sacs we would examine for fifteen days; in one instance for twenty days. In the celloidin sacs we followed it up as many days as we had sacs. We started out
6431 to have ten sacs for ten days; occasionally one would get broken, and the minimum was eight sacs for one of the celloidin experiments.

We have also made experiments in which we have taken the river water and filtered it through a Pasteur filter, and then have platted it out to make certain that no water bacilli had passed through the filter; such raw filtered river water we infected with typhoid bacilli, and found that typhoid bacilli died in this water also in two days in some instances, so that it would appear that there is in the water itself something which destroys typhoid bacilli even if no saprophytes are mixed with typhoid bacilli.

The reason I mention this is because in some of my former testimony I laid particular stress upon the fact that I thought the disappearance of the typhoid bacillus in the experiments reported at that time was probably due to the overgrowth of saprophytic bacteria, whereas, as the result of these experiments, I conclude that there are in this river water certain substances, possibly excreted substances of saprophytes, which alone are sufficient to prevent the growth of the typhoid bacillus, and even destroy it within a very short time.

We have also made experiments in which we inoculated a typhoid bacillus into boiled river water, and in these experiments the bacillus lived longer than it did in the raw but filtered river water. In boiled river water, which contained no living bacteria, into which we inoculated typhoid bacilli, they would live longer than they would in unboiled filtered sterile river water by about three days. In the
6432 parchment sacs the longest they lived was three days. I made one experiment, in which I added to the water from a parchment sac immune serum of this horse and collected the precipitate in the form of a conical glass tube, hoping that if I had escaped any typhoid bacilli by the other methods this way I could enrich the number of typhoid bacilli, if any had been left alive. I tried this several times, always adding the serum of the immune horse, hoping to aglutinate and precipitate the typhoid bacilli of the whole quantity of water used before getting to the bottom, pouring off the rest and adding nutrient material to the residue, because it is a fact that immune serum aglutinates typhoid bacilli, but will not kill them. I was entirely unsuccessful here in finding typhoid bacilli, probably because these experiments were only made after the other ex-
6433 periments showed the disappearance of typhoid bacilli. I was unsuccessful after the third day in the river water by this method to find any typhoid bacilli.

The number of cc. in a liter is 1,000.

I would say that in the manner employed here of using a membrane that allowed osmosis of the fluid outside of the sac in the river, as well as the excresence of the bacteria multiplying inside of the sac

to pass freely in and out, conditions were produced which were as nearly those existing in nature as could be artificially produced. This experiment sheds more light upon the true conditions of the longevity of the typhoid bacillus in polluted streams than we have known in the past.

The fact that even in the raw filtered river water, free of all saprophytes, typhoid bacilli die rapidly, is evidence that there is in this water something which destroys the typhoid bacillus
6434 quickly. That effect must vary in different rivers, and such variation is due to the greater or lesser presence of substances excreted by saprophytes, which explains the greatly varying statements of different authors.

In the experiment with Lake Michigan water we used parchment and also celloidin sacs. * * * During the first four or five days we were largely successful in picking out a typhoid suspicious colony from one of these plates, which immediately gave a Widal test, so that would be set aside. The longest that we found typhoid
6435 bacillus here was for eight days. At the time when they did appear on the ninth day we would take every colony on all of the plates and inoculate every one into Hiss tubes. The
6436 longest that we found typhoid bacilli was eight days. Sometimes we did not find any after four days.

Q. Professor, does this experiment which you have made and introduced furnish you with any basis for an opinion as to the life of a typhoid bacillus in the water of the Chicago River and drainage canal and Illinois River?

A. Yes, sir. As the result of the experiments which have been made by all of us, Prof. Jordan, Prof. Russell and myself, I am of the opinion that typhoid bacilli cannot live in the drainage canal or in the Chicago River or the Illinois River for more than three days.

It is my opinion that typhoid bacilli coming from the sewers of Chicago offers absolutely no danger to the citizens of St. Louis, and that no typhoid bacillus coming from the sewers of Chicago
6437 will live to reach there.

In my opinion typhoid bacilli cannot live for sixty days in the sediment of a river such as the Illinois and then produce typhoid fever. If typhoid bacilli were deposited in the bed of the Desplaines and Illinois rivers between Chicago and Peoria they could not
6440 live for thirty or sixty days and retain their dangerous qualities, because typhoid bacilli die under those conditions in three days.

Typhoid bacilli could not reach, in my opinion, the intake at St.

Louis alive, because it has been proven by our experiment that they die in three days, or less, in the water of the drainage canal and the Illinois River.

The Illinois River, bacteriologically speaking, was less polluted during my investigation than either the Missouri or Mississippi. During all my examinations in the past that has been the case. The effect of the water of the Illinois River emptying into the Mississippi River, since the Illinois River is bacteriologically purer than the Mississippi River, could only improve the conditions by dilution, and the mixing of the Illinois with the Mississippi and Missouri
6441 rivers does not create any added danger to the waters below Grafton, but the very reverse would be true.

I do not consider the sewage from Chicago a menace and a danger to the inhabitants of the State of Missouri, for the reason that the Illinois River at Averyville was purer bacterially than any part of its course from Chicago to Grafton, and that I considered that absolute purification from saprophytic as well as pathogenic bacteria had taken place above Averyville. Contamination produced by sewage of Chicago would be practically removed before it reaches Averyville, according to my investigation and answers in this case, in which I have expressed these convictions at some length. I am speaking now, of course, of bacterial purification and not of chemical substances, but I should judge that also chemical purification has taken place so as to convert dangerous organic compounds into non-dangerous ones as soon as saprophytic life has again decreased, and thereby shows that the end products of organic material have been produced by saprophytic multiplication, and I, therefore, cannot consider
6442 it is a danger or a menace to the citizens of St. Louis or the citizens of the State of Missouri using the water for drinking and domestic purposes.

CROSS-EXAMINATION.

By Mr. Jeffries.

6443 The first day we always found typhoid bacilli in the sacs; in every sac we found them. On the second day we sometimes found the germs and sometimes not. On the third day the same; we found sometimes germs and sometimes not. After the
6444 third day we were never able to find any more.

The reasons given why germs will live in boiled river water
6447 and in filtered river water longer than in raw sewage water. I originally thought that this fact of the disappearance of the

typhoid bacilli was really due more to the overgrowth of saprophytes making conditions of life for typhoid bacilli unfavorable than to the saprophytic products which are diffused through the water, but I have convinced myself now by these varying experiments that there is in the river water sufficient of these saprophytic products present to destroy disease-producing bacteria. Bacteria living but not multiplying in water do not produce any products. The products of the germ are due to the multiplication of the germ. To illustrate: If you inoculate a nutrient bouillon tube with a diphtheria bacillus, and you place that tube in an ice box where the bacillus cannot multiply, it will not produce diphtheria toxin in the tube. It will only produce diphtheria toxin if you place it at blood temperature where the bacillus multiplies and uses up organic material in the bouillon, and when it multiplies it produces excretion products which are so poisonous that one-hundredth of a cc. can kill an average guinea pig in
6450 fifteen minutes. If you prevent that multiplication there will be no poison in the tube.
6456 Osmosis and what it means.

PROF. H. L. RUSSELL.

DIRECT EXAMINATION,

By Mr. Todd.

I am in charge of the Department of Bacteriology in the Uni-
6467 versity of Wisconsin, at Madison. Received my Bachelor's degree from the University of Wisconsin in 1888; remained there as fellow in bacteriology until 1890; went to Europe and studied in Koch's Institute, in the University of Berlin, in the Zoological Station at Naples and in the Pasteur Institute at Paris. In 1890 returned to America and took my Ph. D. degree at Johns Hopkins University; in 1893 assumed the professorship in the University of Wisconsin, at Madison. Since 1894 have been connected with the State Board of Health of Wisconsin as bacteriologist, and in that capacity have been connected with the analysis of waters from a bacterial point of view for sanitary purposes.

Have examined the water supplies of Superior, Ashland, Mari-
6468 nette, Menominee, Merril, Stevens Point, Wausau, Eau Claire, Portage, Green Bay, Beloit, Baraboo and Dubuque. Have studied epidemics in Baraboo, Ashland, Superior, Menominee and Marinette, and am acquainted with the literature of Epi-
6469 demiology; experienced in the interpretation of chemical analysis of water.

familiarity with the water course from Chicago to St. Louis,
6470 and a trip down the same.

Bacteria classified and distinguished. Methods of distribution
6470 and the characteristics of bacteria peculiar to water, as well as saprophytes and parasites distinguished.

6471 Distinction between pathogenic and non-pathogenic bacteria, and the known pathogenic bacteria to man.

Pathogenic bacteria which are water borne.

6741 Bacillus prodigiosis: its characteristics and life history. Its occasional presence in river water.

Have found this bacillus in several instances in the water of the western country.

Familiarity with Dr. Ravold's experiment on the prodigiosis.

6773 Hypothetical question of Dr. Ravold's experiment.

My opinion is that this experiment does not in any way throw any light on the matter of the probable longevity of the typhoid bacillus as measured by the longevity of the bacillus prodigiosis, and the assumption mentioned in the question propounded leads me to believe it highly improbable that the organisms reported to have been found on the 4th, 5th and 8th of December were the same or derived from the organisms which were placed in the water of
6474 the drainage canal at Lemont on the 6th day of November, and as to throwing light upon the question at issue as to the longevity of the typhoid organism I do not consider the experiment would be of any direct value, as the selection of this organism would not give conditions which would permit of a proper interpretation of the results obtained. It is not uncommon to find in water and under other conditions in nature in this region, as well as in other places, organisms possessing the characteristics which simulate those belonging to the bacillus prodigiosis, by reason of the red pigment which they are capable of producing when grown upon the ordinary nutrient media, and which might therefore be mistaken for bacillus prodigiosis unless the characteristics of the germs isolated were studied in
6476 detail, so as to be absolutely certain whether the said organisms belong to the species bacillus prodigiosis or not.

Characteristics and pathogenic significance of the cholera
6477 germ. Anthrax germ. Enteriditis sporogenes and dysentery bacillus.

6478 Characteristics of the typhoid germ; where found. Resemblance to other germs and its relation to the colon bacillus.

6479 Methods employed for determining and identifying the typhoid bacillus.

6480 The longevity of the typhoid bacillus in the human body, in soil and in water.

6481 Experiments upon the longevity of the typhoid bacillus in different kinds of water, with results of those experiments.

Typhoid bacillus does not increase and multiply in nature. Laboratory conditions are more favorable to the longevity of the typhoid germ than the conditions in nature, and the reasons for this opinion.

Typhoid germs will not live as long in polluted as in pure

6482 sterilized water.

My opinion that a typhoid organism will not live as long in polluted water as in pure waters which have been sterilized by heat is based upon the fact that there exists an antagonism between the saprophytic bacteria found in polluted waters, or the by-products of the growth of this organism, and the typhoid organism which exert a prejudicial effect upon the development of the typhoid germ, thereby diminishing its vitality and shortening its longevity.

From my knowledge of the conditions which obtain in the Chicago Drainage Canal and the Illinois River, the longevity of the typhoid organism would not be beyond the average of a few days at the most, say three or four days, for the reason that in those waters the germ would be subject to a number of environmental influences which would exert a prejudicial effect upon the vitality of the organism, and would thereby shorten the longevity of the germ to a period much shorter than would be found in an experimental test carried on under laboratory conditions where the influence of these detrimental factors was more or less excluded.

6483 I have made a large number of experiments on the competition existing between the typhoid and the saprophytic bacteria. These experiments have covered a period of four or five years, and have been conducted along a variety of lines. One group of these experiments was made where typhoid germs were placed in celloidin sacs which were germ tight. These sacs were placed in cultures made of nutrient material, to which material was added such as soil, water and other matters containing diverse forms of saprophytic bacteria. The results of such experiments indicated frequently that the typhoid organisms were unable to grow on the inside of these sacs, even when placed in nutrient mediums, such as beef broth. In many instances not only was the inability to grow marked, but the organisms were actually killed off.

Other experiments were made of a similar character. * * * The fact that under such conditions the organism lost its vitality indicates to my mind a specific illustration of the law of antagonism

which is known to be operative with various organisms among
6484 bacteria, and it is undoubtedly a potent agent in the destruction of pathogenic bacteria in the outside environment.
6485 Other experiments of the same character. Details.
Investigation of the dams on the Illinois River and the effect
6486 those dams have upon the problem of sedimentation.
Sedimentation and its effect by high and low water stages in the Illinois River.
6487 The effect of the law of gravity on bacteria.
Sufficient water could not be discharged through the canal
6488 which would preclude the operation of sedimentation in the Illinois River.
6489 The problem of self-purification of streams and the sanitary significance of dilution discussed.
6490 Whenever the possibility of diseased bacteria is present, the admixture of this relatively germ-free ground water, or even the surface run off, diminishes the number of disease organisms materially which would be present in any given body, although it might contribute in a considerable measure numerous water bacteria. The dilution of any polluted water, therefore, with water coming from these sources would thereby greatly diminish the danger of contracting disease through the introduction of pathogenic bacteria.

The greater the dilution of sewage the less is the danger from infection, and it therefore follows that the dilution of sewage may reach a point where the danger of introduction from sewage which might originally have been dangerous would be brought to such a point as to be relatively harmless.

Chicago sewage and the effect of dilution with Lake Michigan water as manifested by the conditions of the water of the Illinois River.

6491 The addition of Lake Michigan water to the sewage of Chicago is a benefit to the sanitary condition of the Illinois River.

Physical conditions of the Illinois River compared with other rivers in the country for the purposes of purification and sedimentation.

6492 Taking into consideration the conditions which obtain in the Illinois River as to the sedimentation and dilution, and all other conditions that can be observed which permit of the production of chemical and bacterial changes in the sewage as revealed by the analyses reported in Streams Examinations, I do not consider that the sewage of Chicago as discharged into the drainage canal can have any material effect upon the waters of the Mississippi River, except

possibly to increase the amount of such undissolved salts as chlorine, which are not taken out of solution, and which would, therefore, find their way down the stream, and thus probably increase the chlorine conditions of the waters of the Mississippi River as they pass the shores of the State of Missouri.

My opinion is that pollution which would be dangerous to public health which might arise from the sewers of Chicago and enter the drainage canal would not exert any influence on the character of the Illinois River at its mouth at the town of Grafton.

6494 My opinion is that any infectious matter which may be discharged from the sewers of Chicago by way of the drainage canal are deprived of their infectious properties before they have had time to have been carried by the waters of the Illinois River from the City of Chicago down to the City of Grafton, and I know of no data, chemical or bacterial, that can justify a different conclusion. If the typhoid fever organism is destroyed under natural conditions in the course of three or four days, the stage of water in the Missouri River and the Mississippi River would exert no effect, as I can see, on the carrying of infected or polluted water from the City of Chicago to the City of St. Louis.

6494 Prof. Sedgwick's question as to whether any competent expert could say that in a period of low water on the Missouri River,
6495 etc., and the answer to the question by Prof. Russell.

I do not consider that the introduction of the sewage of Chicago into the drainage canal exerts any deleterious effect upon the water supply of St. Louis or upon the waters of the Mississippi River as they pass the State of Missouri.

The conclusion that a typhoid organism will not live in the waters of the Illinois River for more than a period of three or four days is based upon an extensive series of experiments which were arranged and planned jointly with Prof. Jordan, Prof. Zeit and myself, but carried out independently.

These experiments were designed to show how long freshly
6496 isolated typhoid organisms would actually live under conditions as they obtain in the drainage canal and in the water of the Illinois River.

6513 Details of the experiment conducted at Peoria by Prof. Russell.

6514 Table of summaries.

6516 Experiment with commercial agar and a complete explanation
6518 of the experiment.

In the case of the parchment sacs typhoid bacilli were exposed

to the direct contact of all the water or other bacteria which might be present in the samples of water which were placed in the sacs.

In the case of the agar blocks the typhoid organisms were not exposed to this direct contact, but were exposed to those products of the metobolic activity of water and other bacteria which might be present in the outside, and which would find it possible if in solution to pass through the agar block by diffusion, and so possibly act upon the typhoid bacilli themselves which were screened by these agar blocks.

6519 From the results obtained in these combined experiments I should say that the longevity of the typhoid organism immersed in the waters of Lake Michigan would be considerably longer than in the waters of the Chicago River, and the organism would probably be able to live for a period of six or eight days. I should consider that a typhoid organism deposited in the waters of the Chicago River and drainage canal would have a much shorter duration of vitality than in the waters of Lake Michigan, and that such vitality would not extend to a period of more than two or three days.

6520 From experiments which I have actually made when freshly isolated cultures of bacillus typhosus were exposed in permeable sacs in varying numbers, so that the germ content of the typhoid organism exceeded at least the germ content of the water used in the ratio of 100 to 1, or more, and where the organisms were destroyed in the course of about three days, with one possible exception, and that if this was the condition which was obtained under the conditions in which the experiment was made, * * * I would conclude from the foregoing data that the vitality of the typhoid organisms would not in any case be maintained for more than a period of a very few days, three or four at the outside.

6521 In view of the facts that have been obtained from the experiment, * * * I am of the opinion that typhoid organisms, finding their way through the sewers of Chicago into the Chicago River, and thence into the drainage canal, down the Desplaines River and into the Illinois River, would be destroyed before such

6522 water had passed the course of the Illinois River.

* * * The results of these experiments show that the longevity of the typhoid bacillus is less in polluted water than in waters of a pure class. It also sheds light upon the longevity of the typhoid bacillus in the sediment of polluted streams.

Had the experiment been conducted in warm weather, in my

6523 opinion the longevity would have been less.

The behavior of the colon bacillus in soil as compared with water, and a discussion of the purification of soil.

6524 Typhoid bacillus will not live as long in polluted water as in
6525 pure water, and the reasons for it.

I do not think that a typhoid organism would live as long in the water of the Illinois River under the conditions as exists in nature as would be the case in the waters of Lake Michigan.

6526 Explanation for the more rapid death of the typhoid organism
6527 in the waters of the Illinois River than in the waters of Lake Michigan.

There is no evidence which I know of that indicates that the typhoid organism would be capable of living in sediment of such a polluted stream for a longer time than it would in the waters of the same stream.

6525 Conditions that obtain in moist soil and the sediment of running streams differentiated.

It is my opinion that the conditions which obtain in the moist soil and the results which are here found in the sediment of the stream do not furnish any criterion for the determination of the longevity of the organism as found in the sediment of the running stream, and, therefore, the two conditions are not comparable.

The fact that the typhoid fever germs will live several months
6529 in moist soil does not justify the assumption that they would live the same length of time in the sediment of a river.

Reasons for the above answer.

A typhoid germ will live no longer in the sediment of the Illinois River than it would in the waters of the Illinois River.

Q. What conclusion do you draw from the experiment which you have introduced?

6530 A. From all the experiments which I have made on the conditions which obtain where the typhoid organism is exposed in the Illinois River, it is my belief that this organism will lose its vitality under conditions which would obtain in the waters and in the sediment of such a stream in a relatively short period of time, that period of time not exceeding more than three or four days.

6531 Mr. Fuller's account of the presence of typhoid germs in the sediment of Lake Geneva.

From the results of the experiments (Lake Geneva) which have been collected, it is my belief that these experiments were either carelessly performed or not carried out in sufficient detail and under sufficient stringent precautions to warrant the conclusion which is drawn. The reasons for my belief as indicated are as follows:

* * *

6532 It is my opinion, therefore, that the conclusions established in this paper are not justified in the experiments as presented. I

find that this opinion is shared by other bacteriologists, and discredit is thrown on the same by Loeffler, who refers to Lortet's experiments, and places after them an interrogation point.

6534 Mr. Fuller's question and answer in regard to sediment of a
6535 lake and river.

6536 The experiment of Prof. Zeit and Prof. Russell, and its approximation to natural conditions as distinguished from glass bottle experiments discussed.

It is my opinion that typhoid germs coming from the sewers of Chicago would be destroyed in their course in not to exceed four days, and that the diffusion of such bacilli in the waters of the drainage canal would not be a danger and a menace to the inhabitants of St. Louis using the water of the Mississippi River for drinking and domestic purposes.

The effect of the settling basins at St. Louis as a protection to the citizens of St. Louis against infectious matter in the waters of the Mississippi River.

6538 Inasmuch as typhoid organisms are destroyed before reaching St. Louis, I must say that the settling basins afford no protec-
6539 tion against the sewage of Chicago. The protection which is afforded would be from those placed adjacent to St. Louis in which the typhoid organisms would not be killed during the journey from such places to the sedimentation basins at St. Louis.

EPIDEMIOLOGY.

What the term means.

I have examined the typhoid statistics of the Illinois, Missouri and Mississippi water sheds above St. Louis, and have examined the mortality statistics of the city of St. Louis.

6541 Method of interpreting mortality statistics and discussion of the mortality percentage method and the ratio methods expressing the number of deaths from any given disease based on population.

The fallacy of the mortality percentage method.

6542 Typhoid infection from rural districts.

6543 Epidemics caused from rural infection.

I should regard that evidence which is to be adduced from the chemical and bacteriological study of such waters as affording the best possible means which we have at our command to determine
6543 whether such waters are likely to serve as carriers of contagion. The value of chemistry and bacteriology to a sanitarian.

The modes of causation of infection diseases.

6544 The different sources of infection in typhoid fever.

Q. Is it a legitimate inference that because typhoid fever increases in a city that such increase is due to the increase in infection of the water supply?

A. By no means, for it has been abundantly proven in a considerable number of cases that the organism of typhoid fever is capable of being introduced into the body in other ways than

6545 through the medium of infected water.

Assuming that the reports as to the typhoid death rate for the city of St. Louis for the years mentioned are true, and taking into consideration the conditions which obtained on the water sheds of the three rivers mentioned and the fact that there are sources of pollution from which typhoid organisms might arise which are not as far removed from the city of St. Louis as would be the case in the city of Chicago, and taking into consideration further the results of the typhoid experiments which have been made and which have been detailed in the foregoing answers, I should say there was no scientific reason which justifies the conclusion that the increase of typhoid fever in St. Louis as reported in the Board of Health reports for the years 1900 to 1903, inclusive, is due to infectious matter which is derived from the sewers of Chicago by way of the drainage canal.

6546 The decrease in virulence of the typhoid fever germs, discussed.

I have made a study of the so-called "germ diseases," also typhoid fever and malaria fever from the standpoint of the bacteriologist and clinician, also the proper diagnosis of fevers known as typhoid and malaria, and I have studied the same sufficiently to give an

6547 expert opinion.

The symptomology and diagnosis of typhoid, intermittent, re-

6548 mittent, typho-malaria, congestive and simple continued fevers, discussed.

The terms remittent, intermittent, typho-malaria, congestive and simple continued fevers are relics of old methods of distinction which attempted to differentiate these febrile changes merely on the basis of symptoms which are most evident. They are not recognized by working bacteriologists or clinicians of the present time as being satisfactory names for specific types of fevers.

The use of these terms as applied to vital statistics collected under present day conditions indicate that the causes of death were not classified as they should be, and would therefore lead one to

6549 place less reliance on such statistics than would be the case if they were more accurately classified.

From the study of the statistics mentioned in the foregoing question and from the general knowledge of the relation which these diseases bear to each other and the liability of making an improper diagnosis between them, I do not consider that the number of deaths reported in the vital statistics of the Board of Health of the City of St. Louis for the years 1890 to 1903 inclusive, represent the total number of deaths from typhoid fever which actually occurred in that city in that interval.

Taking into consideration the fact which is well recognized by sanitarians that fevers classified under these heads are in a large measure found to be fevers which by modern diagnostic methods would be recognized as typhoid fever, it is my opinion that the statistics which include a large proportion of fatalities as due to fevers of this class, do not represent the true conditions which obtain in that city with reference to the total typhoid death rate.

In my judgment the value of the statistics assumed in the hypothetical question rests in a large measure on the more or less imperfect diagnosis which has been made by physicians reporting those deaths to the City Health Department; inasmuch as many practicing physicians are not personally familiar with modern diagnostic methods which are employed in the most advanced practice in the diagnosis of typhoid fever and malaria and the differentiation of one from the other, it frequently follows that the old expression based upon the symptoms of the fever which used to be used are frequently used at the present time by such physicians when reporting the cause of death. Moreover it frequently occurs that symptoms noted in cases of typhoid fever are not sufficiently distinctive to enable a physician to recognize with certainty whether he is dealing with genuine typhoid fever or malaria, and consequently owing to the tendency to retain these old terms in the description of diseases, it actually follows that many of the typical cases which are more or less obscure in their symp-
6550 toms are reported in the cause of death as remittent, inter-
6551 mittent, typho-malaria, congestive and simple continued fevers.

In my opinion it is practically impossible for any one to give an accurate idea as to what percentage of the deaths reported under these headings assumed in the hypothetical question as occurring in the City of St. Louis inasmuch as the majority of the cases terminating fatally are now diagnosed as typhoid fever, it is undoubted-
6552 ly true that a large proportion of these deaths so reported should be classed as typhoid fever.

Owing to the fact that the disease of malaria as it exists in the United States is a disease resulting in an exceedingly low mortality, it is undoubtedly true that the number of cases reported in the foregoing hypothetical question and which should be classed as genuine malaria is exceedingly small. * * * The results of this character are shown directly by the history of malaria cases which have been recorded in the Johns Hopkins hospital. Malaria used to be very frequently reported as the cause of death in the city, but with the introduction of the method of making blood examinations the number of cases now reported show that the total number of deaths has been reduced to a small fraction of what it used to be reported. Inasmuch as modern methods of diagnosis have enabled the clinician to classify a larger proportion of specific febrile causes under the heads of typhoid fever and malaria which in former years were generally classified and based on symptoms of the disease, it is well recognized by bacteriologists and clinicians that the continuation of the use of these traditional terms is merely to describe the symptoms of the disease, and is an improper classification from a scientific standpoint, and is no true indication of the mortality which exists with reference to typhoid fever and malaria. * * * I should therefore consider that it was generally probable that a large proportion of these diseases which are designated for convenience as column "B" for the respective years, should be placed in the column which

6553 includes the reports of the fatalities due to typhoid fever.

6554 Assuming that by far the larger proportion of the deaths which are reported in the report of the Board of Health of the City of St. Louis for the years covered in the foregoing question under the various headings of fevers were really deaths which are attributable to the disease of typhoid fever, and therefore should be added to the totals which were actually reported in that city for those years under the caption "Typhoid Fever," and taking into consideration statistics presented in the foregoing question, I should consider that the said statistics do not show material alteration which could be deduced with certainty in the typhoid fever mortality of the City of St. Louis from the years 1899 to 1903.

The letter written by the Board of Health of the City of St. Louis to the physicians of St. Louis in 1900, I consider that such letter did manifest itself in the statistics.

6556 The way in which such letters manifest themselves in the vital statistics of St. Louis.

If consideration is given to either of the columns designated typhoid and typho-malarial death reports as reported by the Board of

Health of the City of St. Louis, it is my opinion that neither of these reports of the fatalities do express the actual typhoid mortality of the City of St. Louis for the period mentioned.

This opinion is based upon the fact that it is highly probable that a large majority of the cases reported in the column designated "B" really were cases of typhoid fever, and further taking into consideration the effect which would be produced by the issuance of letters mentioned in the foregoing questions, it would lead to a more correct diagnosis of the disease of typhoid fever, and the report of the same under the caption of Typhoid Fever, I should consider that the results as presented in the foreging questions do not represent the typhoid conditions which actually occurred if these tables are
6557 considered separately.

I should consider that from the standpoint of the bacteriologist, clinician or statistician, that in order to get at the true typhoid mortality which would exist in the City of St. Louis, that it would be necessary to add to the statistics which they have reported as typhoid a large proportion, at least, if not practically all, of the cases which have been reported under the caption which has been designated in a previous question as column "B," to those of the figures
6558 of the given typhoid cases.

By adding together 50 or 100 per cent. of the typho-malarial deaths and the typhoid deaths, and which in my judgment represents data showing the actual amount of typhoid fever which did occur from the period mentioned much more correctly than is shown by consideration of the reported deaths, I should consider that the actual number of typhoid deaths which have occurred in St. Louis since the year 1900 shows no increase over the death rate in that city from this disease for the period mentioned prior to that time, with the possible exception of the recognized epidemic which occurred
6559 about the year 1892.

These statistics show that there has been no increase in the actual number of typhoid deaths which occurred in the City of St. Louis from January, 1900, to 1903, inclusive, when the typhoid death rate for this period is compared with that which actually prevailed in the City of St. Louis for the period embraced between the
6560 years 1890 and 1900, inclusive.

PURIFICATION OF STREAMS.

The waters of the Mississippi River west of the centre thread of said stream at the chain of rocks is not less valuable for drinking purposes and not more liable to carry water borne diseases now than

it was before the sewage of the Sanitary District was delivered into the drainage canal and through it into the Illinois River.

Increased speed in the current by the increased volume would cause an overflow of the banks of the river, and the sewage from the towns of Joliet and Peoria would be removed before such sewage reached the Mississippi River, so that it would not materially alter the conditions of the Mississippi River, except in the case of
6561 suspended salts.

Professor Sedgwick's question that in sewage polluted streams the typhoid germ might live in gradually diminishing numbers for weeks or months, or even years, is shown by the experiment to be contrary to evidence, for the organism dies out with especial
6562 rapidity in sewage polluted waters.

I consider the assumption that typhoid fever germs could pass from the sewers of Chicago by way of the drainage canal to Lake Peoria and be deposited there in the bed of that lake for a period of one month as one that is untenable, and in the light of experimental inquiry not in accord with the facts, and it is my opinion that under no normal conditions which could obtain in nature as they now exist that the typhoid germ would be able to pass from Chicago to Peoria and not be destroyed before the end of the periods covered
6564 by the question.

It is my opinion that large numbers of typhoid organisms derived from the Chicago sewage would not be found in Lake Peoria above the City of Peoria, and considering all the conditions involved, I should say that my opinion is that at no time under actual conditions would the number of typhoid organisms ever be as great
6565 at Peoria as they would be at the Bear Trap dam.

There is every reason to believe that the organisms of typhoid fever which might be present at the Bear Trap dam would be
6566 destroyed entirely before reaching Lake Peoria.

Owing to the fact that the pollution or infection which would be deposited in the Illinois River from the sewage of Chicago would be practically purified by the time it has been carried for a portion of its way down the river on the way from Chicago to Grafton, it would naturally follow that the waters of the Illinois River which enter the Mississippi River at Grafton would not be a menace to the inhabitants of the Missouri shore on the Mississippi River, if such water was used for drinking purposes at points below on
6568 the Missouri shore.

Assuming that there was no typhoid fever pollution of the waters upon the water shed of the Mississippi River or its tributaries

above the intake of the St. Louis waterworks other than that derived from the Sanitary District of Chicago under the conditions assumed, and taking into consideration the time of flow and the vitality of the typhoid organism in the waters of such a river, I do not believe that the typhoid organisms deposited in the waters of the Illinois River would find their way by the way of the Illinois River to the water supply of the City of St. Louis through the intake at the chain
6570 of rocks.

(Professor Sedgwick's question, assuming that a large number of typhoid fever germs pass through the sewers and pass out of the Illinois River into the Mississippi River water.)

I would say that I know of no evidence based upon analyses, experiments, or otherwise, that would justify the assumption that the typhoid organisms deposited in the Chicago drainage canal would pass by way of the Illinois River into the Mississippi River and find their way into the water supply of the City of St. Louis at the intake tower at the chain of rocks.

6571 Asiatic cholera.

Professor Sedgwick's statement that sewage prolongs the longevity of typhoid is answered by Professor Russell as follows:

"It is my opinion that the deposition of sewage of Chicago into the drainage canal does not increase the longevity of the typhoid organism deposited therein, but, on the contrary, is a potent factor towards the more rapid destruction of the vitality of the typhoid organisms than would be the case if such sewage was not so
6573 deposited."

"When sewage is added to the water in an unsterilized condition, such as would exist when normally deposited in drainage canals, the addition of such sewage does not increase the longevity of the typhoid organism, but, on the other hand, is a distinct factor in
6573 the early death of the typhoid organism."

The increased population of Chicago, with an increased amount of sewage discharged into the maximum amount of the capacity of the drainage canal, would not materially alter the conditions of the Illinois River at its mouth, and typhoid organisms entering the drainage canal would not survive as far as the mouth of the Illinois River, and consequently would have no effect upon the sanitary condition of such waters at Grafton, and it is my opinion, then, that no
6574 immediate and impending danger would exist to the people of
6575 St. Louis or those living on the Missouri side of the Mississippi River below Grafton, and therefore that no effect would be produced upon such people who would use the water of the Mississippi River for drinking purposes.

Taking into consideration the chemical and bacterial knowledge which I possess of sewage of the drainage canal, the variations of different seasons of the year, together with different stages of the river, the introduction of such sewage at Chicago would not be a danger and a menace to the inhabitants of the State of Mis-
6575 souri or the City of St. Louis.

And it is further my opinion, that none of these substances in the sewage of Chicago would reach the City of St. Louis in a
6576 dangerous state. Typhoid germs cannot live for a period of
6577 one to three years or be able to make the journey from Chicago to St. Louis in a virile state, and in my opinion the water supply of St. Louis is not contaminated, polluted or injured by the sewage of Chicago.

6577 The presence of the dams in the Illinois River, or their re-
6578 moval, would have no effect on the sanitary problems of the sewage of Chicago affecting the City of St. Louis.

The Mississippi River is not to be regarded as a thoroughly safe and potable water supply, suitable for all domestic and drinking purposes, and was not prior to January, 1900.

The Illinois River, during the same period, was not to be regarded as a safe supply; neither is the Mississippi and Missouri, exclusive of the Illinois River, a safe and suitable water supply.

I consider that the use of the waters of any drainage system, such as obtain in the Mississippi and Missouri Rivers, is not to be considered a safe and suitable supply for drinking pur-
6579 poses.

The sewage of Chicago will have no deleterious effect upon the inhabitants of the State of Missouri in using the waters of
6580 the Mississippi for drinking purposes.

In view of the fact that the conditions which obtain in the City of St. Louis and the condition of the water sheds which are immediately adjacent to this city, in view of the fact that the typhoid fever death rate of that city is dependent upon other conditions than those due to the water supply of that city, and may be materially influenced by operation of many other factors, in view of the conditions which obtain in the Illinois River with reference to the process of purification which would occur in the sewage of Chicago when deposited in the drainage canal, and taking into consideration all the knowledge which I possess with reference to all data which bear directly or indirectly upon the question involved, it is my opinion that the increase in the typhoid deaths, as reported in the City of St. Louis, assuming such increase to be true, which have occurred

since the opening of the drainage canal, cannot beyond all reasonable doubt be attributed as a direct, immediate and approximate
6581 for such increase to the opening of that drainage canal.

CROSS-EXAMINATION,

By Mr. Jeffries.

Difficulties in making determinations for pathogenic bacteria
6586 in water supplies.

Q. State whether or not, in your opinion, typhoid fever germs lived longer in the waters of the Chicago River prior to the opening of the drainage canal than they will now live in the waters of that river in the canal.

A. My opinion is that the changes which have been produced in the Chicago River through the opening of the drainage canal are not such as will greatly modify the death rate of the typhoid organisms when exposed under these two conditions. This opinion is based upon my belief that in either instance the degree of concentration in the water of bacterial by-products and the presence of saprophytic bacteria themselves would be sufficient to cause an early death
6591 of typhoid organisms placed in this water.
6592 (Number of typhoid epidemics personally investigated.)

I do not consider that the life of the typhoid organism as illustrated by the experiment cited does range for a range
6596 of one to nine days.

Q. What significance do you attach to the presence of the organisms on the ninth day in sac 15 of the "Z" strain?

A. Taking all of the data which is incorporated in the table at hand, and taking into consideration the fact that in 144 tests made on the first three days the typhoid organism was found in 69 cases, and further taking into consideration the fact that in 318 analyses conducted subsequent to the third day only one organism was found which was proven to be typhoid in character, and further taking into consideration the fact that the results of the experiment are so overwhelmingly concordant, with the exception of this single case, it is my opinion that the conclusion which is to be drawn from this experiment, taken as a whole, warrants the conclusion that typhoid organisms exposed under the conditions of the experiment would be incapable of retaining their vitality in the waters of the Illinois River at Averyville for a period which exceeds that reported in my
6596 direct evidence.

Taking into consideration the care and precaution that was

used by you in making the determinations contained in the tables which you read in your direct testimony, and assuming that typhoid fever dejecta is deposited into a running stream which flows for a period of nine days, at which point the inhabitants of a city receive their water supply, and knowing that you have observed the presence of the typhoid bacilli during the series of examinations which you made in the water at that point, assuming bacterial conditions of that water to remain or be practically as contained in the sacs with which the observations were made, would you warrant that water as free from typhoid bacilli and therefore suitable for domestic and drinking purposes?

A. Taking into consideration the fact that typhoid organ-
6600 isms deposited in running streams would not be subject under natural conditions to such conditions as outlined in the foregoing question, for the reason that in such flow there are factors operative, and always operative, which are not assumed in the foregoing question, and which must be assumed if the conditions are made to refer to conditions that actually do obtain in a flowing stream, and taking into consideration all the knowledge which I possess from a bacterial analyses of waters so exposed and the conditions which are referred to, it is my belief that waters discharged into a stream, the character of which corresponded to the conditions which are assumed in the questions and which under such conditions are effected by these other factors which are always operative, it is my opinion that typhoid organisms would not be found in such waters when the period of flow was of nine days' duration.

Q. But, Professor, assuming, aside from the natural conditions, that the water remained in the river as it remained in the sacs for nine consecutive days, and on the ninth day you found typhoid bacilli present as shown in your observations, would you consider that water as being free from typhoid bacilli at the end of the ninth day?

A. It would be impossible to base a recommendation of such a character unless all the facts which bear upon this question were taken into consideration, and if those facts were in accordance with the facts as represented in the experiment referred to in which analyses were made in large numbers and at daily intervals, and in which out of this series of analyses the typhoid organism was found abundantly the first day, the second day and the third day, but not found at any subsequent day, although frequent daily examinations were made, except in one single solitary instance on the ninth day, and was found in no other instance thereafter, although examinations were continued for double this length of time, I should, under these circum-

stances, consider that I was warranted in assuming that the typhoid organisms introduced in such water would have disappeared so completely that under no conditions would the water have been able to produce disease if it had been consumed by human beings.

Q. Under the facts assumed, and at the end of the ninth day, and at the point the end of the ninth day, you would recommend to the people that they could drink that water with impunity, as far as the effect of typhoid fever germs was concerned?

A. The recommendation as to whether a water supply is pure or suitable for domestic use, presupposes conditions which are not assumed in the foregoing question, and which must of necessity be taken into consideration before any such recommendation can be made, and a water supply which is known to contain typhoid bacilli must, therefore, be subjected to exceedingly stringent examination before one would be warranted in making any such recommendation as indicated in the question.

Q. Do you mean a stringent examination for the purpose of determining the presence or non-presence of typhoid bacilli?

A. I do.

Q. Do you consider the observation and examination which you made of the water contained in the sacs shown in your tables to be a stringent examination of that water for the purpose of detecting the presence or non-presence of typhoid bacilli?

A. I consider that the examinations which were made of the analyses of this water were sufficiently stringent to have detected the presence of the typhoid bacilli if such had been present.

6602 Q. Then, under the conditions assumed in the preceding question, that if water in a running stream ran nine days, was during the time in the same bacterial condition as the water contained in the sacs which were used in your experiment and underwent the same bacterial changes, containing typhoid bacilli which also underwent the same changes, that water would be suitable for drinking purposes at the end of the ninth day and at the place reached at the end of the ninth day?

A. The conditions which were stated in the assumptions named in the question are so entirely foreign to what do exist when waters find their way in a flowing stream, that the comparison which is made between the conditions of this experiment and the conditions which would occur when typhoid organisms were deposited in a running stream for nine days' flow, are such that I am unable to state exactly what would occur under the conditions assumed, but when I take into consideration the fact that in the case of water containing approxi-

mately 5,400,000 typhoid bacteria in a given volume that the exposure of that water, under the conditions as described in the fore-
6602 going answers, failed to reveal the presence of typhoid organisms in all but one case out of the entire number examined on the ninth day, so that the vitality of this enormous number of organisms had been entirely lost, with the exception of the single germ referred to, except in the case of the first three days, when typhoid organisms were demonstrated, I should consider that the conclusion which is based upon the results which were obtained in this single organism alone, and not the whole of the results of the experiment, are not proper as indicating what the condition of affairs would be which would occur in nature.

RE-DIRECT EXAMINATION,

By Mr. Todd.

Q. With these assumptions supplied as you have indicated, what recommendation would you make for domestic and drinking purposes under the conditions obtained in the hypothetical question as to the quality of water after running nine days from its source of infection, assuming that all other sources of infection were eliminated?

A. Assuming that all other sources of infection are eliminated, when water was exposed under natural conditions in a flowing stream, I should regard this period of flow as sufficient to result in the destruction of the typhoid organisms, and would, therefore, re-
6606 gard such supply as not capable of producing typhoid disease.

6607 ISHAM RANDOLPH.

DIRECT EXAMINATION,

By Mr. Todd.

6608 Qualifications and experience.

Conditions of the Chicago River as they were in 1880 and as
6609 they continue to be in 1900.

6610 The sewage system of the City of Chicago described.

6612 Map of the sewage system of Chicago.

6613-6614 The Illinois and Michigan canal described.

6615 Conditions of the summit level of the pools in Joliet.

6616 Condition of the water in the Illinois and Michigan canal from Chicago to La Salle described.

6616 Sanitary and ship canals described.

6617-6619 General outlines of sanitary and ship canals described.
6619 Bridges constructed across the drainage canal and the reasons
6620 for their construction.

Work was begun on the drainage canal on the 3d of September, 1892; the water was let into the channel on the 2d day of
6620 January, 1900. On January 17, 1900, the water was permit-
6621 ted to flow over the Bear Trap dam.
6621 Work on the Chicago River.

The grade in the channel falls 5.62 feet and with the minimum depth the water surface is supposed to be parallel to that grade, so that when there is only twenty-two feet of water in the channel, which may sometimes happen, the fall of the water surface
6622 should correspond with the water in the channel, 5.62.

The length of the channel from Robey street to Lockport is 28.05 miles; from the mouth of the river to Robey street is six miles.

The variableness of the levels of Lake Michigan.
6623 The cost of the drainage canal up to January, 1904, was
6624 $42,503,168.80.

Boundaries of the Sanitary District as first laid out embraced 185 square miles; under the new bill 78.6 square miles of terri-
6624 tory was annexed on the north and 94.48 square miles were an-
6625 nexed on the south. The whole city is now in the Sanitary District.
6626 Map of the Sanitary District.
6627 Plans for caring for the annexed districts.

Population of the Sanitary District, 1,942,000.

Plans used by the Sanitary District in conjunction with the City of Chicago for diverting the sewage of Chicago from Lake
6628 Michigan.

The maximum capacity of the Chicago drainage canal, 825,000 cubic feet of water per minute.
6629 The average flow per week of the drainage canal since its opening.

Q. During the period of 1900 were the dams at Lockport entirely closed at any time?

A. My recollection is that they were for a few hours, I think it was on two or three occasions when vessels got stuck in the channel, when the dams were shut off long enough to relieve them. I have no knowledge ever flowing through to the lake but once since the channel was opened. It was a general freshet and that flow began to go towards the lake, and as soon as that was noticed we checked
6629 it in a very short time; it did not last probably more than two
6630 or three hours.

Maximum, mean and average flow through the Illinois and
6630 Michigan canal for the years 1900 and 1903.

The per capita consumption of water in the City of Chicago for 1900 was 190 gallons; in 1901 was 195 gallons, and for 1902 was 197 gallons.

The maximum, minimum and average flow of the Desplaines River from 1900 to 1903. The mean average flow of the Desplaines, the Chicago drainage canal and the Illinois and Michigan canal
6631 at Dam No. 1, where the three waters commingle.

Chart showing the pollution at Dam No. 1, based upon the mean discharge from the drainage canal, the Illinois and Mich-
6633 igan canal, the Desplaines River, as well as the population discharging sewage at that point.

6634 Explanation of the chart.

Q. What is the proportion of sewage to the mean discharge of the drainage canal, as evidenced by your tables for the three years, 1900, 1901 and 1902, respectively?

A. The ratio is 1 to 9.2, either expressed in gallons or cubic feet, for 1900; for 1901 the ratio is 1 to 10.2; for 1902 the ratio is 1 to 10.4.

Q. What are the proportions of urine and fecal matter to the mean discharge of the canal for the three years above mentioned?

A. One in 5,429 for 1900; one in 6,211 for 1901; one in
6635 6,310 for 1902; the comparison being made in pounds.

Table No. 2, marked Pollution of Sanitary Canal, based on
6636 clause on page 12 of the report of the hydraulic engineers.

Explanation of the table. This table is based upon a consumption of water of sixty gallons per day per capita. The proportion of sewage to the mean discharge was one part in 29.1 parts. The proportion of urine and fecal matter to the mean discharge of the
6637 canal was one part in 15,249, expressed in pounds.

6639 Population curve of the City of Chicago.

6641 Table of population of the City of Chicago.

6644 Table of excreta.

6646 Table of pollution of the Illinois River from its tributaries.

6647 Explanation.

Q. From the tables which you have introduced, what conclusion do you draw from those tables?

A. I conclude that the natural pollution of the Illinois River is due to the urban and rural population draining into its water shed, exclusive of all sewage coming from Chicago, is more polluted than the waters of the Illinois River are when combined with the dis-

charge from the Sanitary Canal after the opening of said canal. In the conditions which obtain, without considering the discharge from the Sanitary Canal, the pollution is one in 17.48; the pollution
6648 considering the Sanitary Canal is one in 34.3, measured in quantity.

6649 Map of the various water sheds tributary to St. Louis.

6650 Familiarity with the water sheds between Chicago and St. Louis and a description of the physical conditions.

6651 Description of the locks on the Illinois River, with the distances.

Q. Mr. Randolph, prior to the opening of the drainage canal, what was the character of the water that went south in the Illinois and Michigan canal by the Bridgeport pumping works?

A. It was water in a highly polluted state.

Q. When did those pumps begin to pump the sewage of the Chicago River into the Illinois and Michigan canal?

A. The pumps were installed, that is, the set of pumps were put in, after the opening of the canal. The canal was deepened between 1865 and 1871, and the flow was only about 9,000 cubic feet per minute. It was insufficient for the sewage and the pumps were put in the latter part of 1884; the operation was commenced about the end of the year 1884. From 1884 to 1900 the average amount of
6652 sewage pumped was approximately 50,000 cubic feet per minute.

Map and chart showing the population of the water sheds of
6654 the Illinois, Mississippi and the Missouri Rivers above St. Louis.

Population of the Illinois River, exclusive of Chicago, 599,751.

Population of the Mississippi River above Grafton, 1,839,586.

Population of the Missouri River above its mouth, 1,650,594.

Population lying tributary to the Mississippi River upon the
6654 three water sheds above St. Louis, including Chicago, 5,788,506.

6654-6655 Population of the Sanitary District, 1,698,575.

6655 Gauge readings of the Desplaines River at Lockport, Illinois

6656 River at Peru, which were asked by Professor Van Ornum.

6657 The volume of flow of the Illinois, Mississippi and Missouri

6665 Rivers, and discharge charts.

6666 Profile map of the waterway from Lake Michigan to Cairo.

The profile is constructed in the usual manner, the vertical scales being very much exaggerated. It indicates by a broken line the bed of the channel from the best data which we have been able

to obtain, and where the hydraulic gauge line is not regulated by dams it is shown by wavy black line. The pools made by the dams are indicated by straight lines, slightly descending. The profile commences at Lake Michigan, follows the course of the Chicago River and the drainage canal through to Lockport, and thence on through
6667 the Desplaines, the Illinois and Mississippi Rivers to Cairo.

Float experiment to ascertain the velocity of the current from
6667 Chicago to St. Louis.

6669 Table showing the results of the experiment.

Q. What was the mean time from Lake street in the City of Chicago to the Eads bridge at St. Louis?

A. Eighteen and one-half days.

Q. What was the stage of the river at the time this experiment was made?

A. I can hardly call it the mean stage of the river; it was not a flood time, that is, not anything like a maximum flood, nor was it low water; it was a full river, but not a flood. I think it was above the mean average flow of the river.

6671 Gauge readings at the time the experiment was made.

The seventeenth annual report of the Health Commissioner of St. Louis for the year 1893 contains the following:

"ILLINOIS RIVER POLLUTION: The existing indisputable proof of the contamination of the Illinois River by constant discharge into its channel of a large quantity of sewage, and the fact that it joins the Mississippi a number of miles above the city of the intake of the local waterworks, suggested the reflection that with the completion of the gravity drainage canal now under construction from the Chicago River to the basin of the Illinois River, the sanitary peril attending the unguarded use of the Mississippi River water could not in justice be longer unnoticed or ignored. This consideration led to the recommendation that special inquiry be instituted in this regard, and resulted in a chemical examination by the department of
6672 samples of water taken from the channel of that stream in October."

"The report on August 21st further shows, among other things:
* * *

"Be it Resolved by the Board of Health of the City of St. Louis, that his honor, the Mayor, and the honorable municipal assembly, be and are hereby respectfully requested to memorialize Congress concerning this matter; that a suitable commission be appointed without grievous delay with power to fully investigate the subject of the extent of the present and prospective pollution by sewage from Chicago

of the Illinois and Mississippi Rivers in order that the probable amount of danger to the public health therefrom, and all other pertinent facts in regard thereto, may be made known."

Again, in the same report, on September 28th, the following resolution was offered and referred:

"Ordered by the Board that the city chemist be and is hereby directed to proceed to collect samples of water for chemical analysis, and such other samples as may by the Board be deemed necessary, from the channel of the Mississippi River at the chain of rocks; such samples to be taken in such number and at such times as may be determined by the Health Commissioner, and the results of the analysis of same, and such other material information as may be
6674 elicited, be reported from time to time to this Board."

The same report for October 16th contains a communication from the city chemist stating that he collected samples from the chain of rocks, Mississippi River water between Grafton and a point five miles north of the Illinois River, samples from the Illinois River three miles north of its mouth at Grafton, and the Mississippi River
6674 between Alton and the chain of rocks. This was done in con-
6675 formity with the resolution before mentioned.

These samples were analyzed and under date of December 4th the city chemist transmitted his report of the analyses, show-
6675 ing the condition of the water from a chemical standpoint.

On December 21st the Board of Health adopted a report wherein it was suggested, among other things, as follows:

"It is suggested, therefore, by your committee, that before finally ordering the city chemist to proceed with the work proposed, it will be well to ascertain the attitude or opinion of those city authorities upon whom it will be incumbent to move for the protection of our water supply, either by legal proceedings, petition to Congress or otherwise. The whole matter was then referred to the Mayor."

At the regular meeting January 8th, a letter was received from the Mayor, on page 45 of the Health Commissioner's report of the City of St. Louis, as follows:

"I have received yours of the 22d, with accompanying reports bearing on the subject of the quality of the water of the Mississippi River between the chain of rocks and a point five miles above the mouth of the Illinois River, as recently determined by the city chemist. Also charts illustrating the results arrived at by chemical examination, and have examined these charts and reports as carefully as my want of technical knowledge will permit."

"The result of the work is, undoubtedly, presented in a very

graphic manner; indeed, it seems to me that a technical knowledge is hardly necessary to understand the results as shown by the reports and charts before me. Assuming that the work of the city chemist, so far as it was, was thorough and reliable. I have no reason to doubt that the City Chemist, Teichmann's, work can be depended on as representing the true conditions. It is my understanding that this investigation was the result of a suspicion that our water supply was being contaminated by Chicago sewage coming from the Illinois River. Briefly, then, I find from the charts before me conditions as follows:"

"Substances supposed to contaminate drinking water in dangerous quantity in Illinois River; also spots in the Mississippi River between the mouth of the Illinois and the chain of rocks and in the mouth of the Missouri River. I find, however, that at Grafton, about one and one-half miles below the mouth of the Illinois River, the water is purer than at any other point in the river between Grafton and the chain of rocks. That is to say, nothing of the objectionable substances seem to exist in dangerous quantities one and one-half miles below the supposed source of contamination, while the pollution increases and diminishes below that point at regular intervals. This, it seems to me, tends to disprove the theory that the contamination, if there be any, at the chain of rocks, comes from the Illinois River, and goes to show that the offensive substances found in spots along the river between the mouth of the Illinois and the chain of rocks are due to local causes. The comparative purity of the water at Grafton seems to be inconsistent with the theory that the water below that point is contaminated from the water from the Illinois River. The conditions existing at the mouth of the Missouri River, as shown by the chart, suggest that as a much more probable source of
6677 pollution than the Illinois River."

Dr. Teichmann's report requesting a continuation of the
6678 analysis.

6679 Report of the Federal Rivers' Commission, as found in the Board of Health Reports of March 31, 1895, on page 11.

Formation of a local commission under municipal authority to inquire fully into the condition of the water supply at St. Louis, the construction of the drainage canal, and its influence upon the water supply of St. Louis, and a bill in Congress creating a federal commission, as it appears in the Board of Health report for 1895-1896 of St. Louis.

WELLS.

On page 12 of the seventeenth annual report of the Health Commission of St. Louis appears the following:

"The examination of water taken from surface wells in different parts of the city progressed memorably during the year, and a number of these sources of contaminated water supply for household have been condemned. The standard of allowable impurity established for the purpose of this undertaking is quite liberal, but even as thus measured, very many wells were found to contain water largely unfit for human consumption."

On page 63 of the same report appears the following:

"Number of samples of well water analyzed, 2; private wells,
6685 239; public wells, 8; number of impure wells reported for condemnation, (a) private wells, 41; (b) public wells, 5."

On the same page, among other things, appears the following:

"Although the analyses of wells thus far made do not represent every ward in the city, the comparatively large number of wells found to be impure, averaging about one out of five, fully justifies the vigorous continuation of these examinations."

Again, on page 215, in the annual report of the Health Com-
6686 missioner for May 31, 1895, under the head of Wells Contaminated and Total Number of Wells, appears, "Total, 59 wells;" and, again, on page 65 of the same report appears the following: "WELLS: 59 wells have been contaminated by the Board of Health and very few have been closed. The standard which was established by the Board of Health in relation to wells should be legalized by the Municipal Assembly. Where such water is on any premises and where it is desired to retain the well for stock and washing purposes, a permit to do so should only be given under certain binding conditions. The Assembly should enact the law."

Again, on page 204 of the same report, appears a table showing the distribution of wells with a total number of public wells on
6687 street, 437; total number of wells in wards, 4,848. And again, on page 66 of the nineteenth annual report of the Health Commissioner, in a report of the meeting of August 1, 1895, appears the following:

"A communication was submitted by the Health Commissioner in reference to the report of the city chemist on analyses of the water from seven wells, the water of which is impure according to the standard adopted by the Board of Health some two years ago. The communication was made the basis of the following resolution, which on motion, duly seconded, was adopted:

"Resolved, that hereafter the city chemist shall make no examination of well or cistern water unless by special direction of
6688 the Health Commissioner."

6700 DR. LUDWIG HEKTOEN.

DIRECT EXAMINATION,

By Mr. Todd.

6701 Qualifications and experience.

6702 I have studied in Europe, Sweden, Prague, Berlin.

Q. In connection with the studies you have detailed, have you taken up the question of the proper diagnosis of fever of the
6703 kinds known as typhoid and malaria?

A. I have. I have had experience in diagnosing these fevers in the laboratory and at the bedside, and am qualified to give an expert opinion.

Typhoid fever and the clinical diagnosis; intermittent fever,
6703 remittent fever, typho-malaria, congestive fever, simple con-
6704 tinued fever, described.

Q. Are remittent, intermittent, typho-malaria, congestive and simple continued fevers distinct types of disease and so recognized by pathologists, bacteriologists and clinicians?

6704 A. No, they are not.

Q. What significance do you attach to those terms as applied to fevers when they appear in vital statistics?

6705 A. I think that in a large percentage of the cases they mean typhoid fever.

Q. Assuming in the question the number of deaths from typhoid fever and the number of deaths from typho-malaria, etc., fevers, do the number of deaths reported as occurring from typhoid fever alone in the City of St. Louis properly represent in your opinion the total number of typhoid deaths occurring in that city?

A. No, because of the large number of deaths recorded under the heading of remittent, etc. I attribute the failure of the number of deaths to properly represent typhoid conditions for the reason just given in answer to the previous question, viz.: that the number of deaths attributed to malarial fevers, so called, is in my opinion excessive, and that, of course, depends upon erroneous diagnosis by the physicians in St. Louis. This, undoubtedly, is the result of the teachings laid down from the early period, where these different forms of diseases, especially typhoid and malarial fevers were not distinguished

from one another. I know of no city in the country having as large a death rate from malaria as reported in St. Louis. Malaria
6706 fever is not a prominent cause of death in this country.

The column of intermittent, etc., fevers, in my opinion, means that between 75 and 90 per cent. of those cases probably should be put in the typhoid column. The tables appear to show that until the year 1900, when one of these diseases occurred in considerable
6707 number in a certain month of the year, the other diseases occurred to about the same extent at the same time, whereas, after 1900 the number of deaths from remittent, etc., fevers, is on the whole smaller than from typhoid fever. By adding the totals typhoid and typho-malarial group of figures do not appear to me to
6708 show any increase in typhoid fever mortality since 1899.

The letter sent out by the Board of Health to the doctors manifests itself in those statistics; it would seem to appear in the prominent increase in the number of deaths from typhoid fever associated with a corresponding prompt decrease in the number of deaths from remittent, etc., and other fevers, and, in my opinion, taking the two groups of figures separately, they do not correctly show the typhoid condition for the reason that I believe that a large percentage of the tables include under intermittent, remittent fevers, etc., what really were deaths from typhoid fever, and I think they ought to be consolidated in order to arrive at the true typhoid fever mortality in the City of St. Louis. In my opinion, I think that the approximate truth could be arrived at by consolidating the two tables and then
6709 perhaps subtracting 10 per cent.

By considering the tables together and the increased population in St. Louis, typhoid fever has decreased in the City of St. Louis since 1900. I arrived at this by studying the figures in the table, and they show that up to the year 1895, inclusive, the death rate from typhoid fever appears to be approximately 80 or 90 per cent., whereas, after 1896, up to the period 1900, it appears to be 50 and 55 per cent., that is, the death rate appears to be between 50 and 55 per cent., and between 1900 and 1903 the death rate is about the same.

CROSS-EXAMINATION,

By Mr. Jeffries.

The opinion that I have expressed is based upon my general knowledge and an examination of the health reports, and I
6715 refer directly to this well known fact, viz.: that deaths from malaria fever in temperate climates are exceedingly few and

far between, and the further fact that so far as known the prevalence of fatal malaria in St. Louis, and in the vicinity of St. Louis, has not been marked for many, many years.

Elihu B. Spencer, photographer, prepared views along the Illinois River and made an album and introduced the same in
6734 evidence as Defendant Spencer's Exhibit "C."

6736 E. G. SMITH,

DIRECT EXAMINATION,

By Mr. Todd.

Professor of chemistry at Beloit College, Wisconsin.

I have been there since 1881; graduated from Amherst College in 1877; studied medicine for a year; was instructor in chemistry at Williston Seminary, East Hampton, Massachusetts; then came to Beloit and have been there continuously except for an absence of eighteen months in Europe, studying at Georgia Augusta University in
Germany, where I took my Ph. D. degree in 1883, pursuing
6736 the study of chemistry and minerology.

I took a course in bacteriology at the Boston Institute of Technology; have given practically all of my available time since 1885 to the study of sanitary problems, especially water courses. I have been called to the study of many public water supplies. This would naturally include the lakes and rivers and streams tributary thereto. I have done work upon the Platte River, the Missouri, the Mississippi, the Schuylkil, Delaware, Beaver River in Pennsylvania, and many other smaller streams. The work upon these streams has been the observation of the sanitary qualities of the water and its adaptability
for drinking and domestic purposes, and its suitability for water
6737 supply.

Have investigated typhoid fever epidemics at Baraboo, Ashland and West Superior, Wisconsin, Menominee, Michigan, Rock Island, Illinois, and have frequently been called in where typhoid fever was alleged to be present.

6738 The history of the epidemic at Baraboo.

6739 History of the epidemic at Rock Island, Illinois.

6741-6742 Menominee and Ashland.

FILTERS.

In the prosecution of my sanitary work I have had a great deal to do with different systems of filtration. I have done work upon

filter systems of one sort or another at Davenport, Ia., Rock Island, Ill., Ashland, Wis., Independence and Burlington, Kas., Cedar Rapids, Ia., Beaver Falls, Pa., Warren, Ohio, Brooklyn and Binghamton, N. Y., Denver, Colo., Kankakee, Ill., Eau Claire, Oshkosh and West Superior, Wis., and Burlington, Ia. I have acted under the name of consulting chemist to either the company operating the plant, or the city. I have an intimate acquaintance with every make of the so-called mechanical filters which are made in this country. I have done work upon the English system, been abroad for the purpose of investigating foreign systems of filtration; called upon to recommend types of filters and in consulting capacity regarding the form of filter to be introduced. Have been consulted upon the system of filtration in Burlington, Ia., New Brighton, Pa., Ashland, Wis.; the matter of filtration at Menominee, the readjustment of the plant at Cedar Rapids, working over the plant at Oshkosh, made a report upon the proposition of establishing a filter plant for the City of Minneapolis. I investigated the system of filtration at London, Paris, Antwerp, Berlin and Hamburg.

Am acquainted with the literature bearing upon typhoid epidemics, and have made it a special study. Have devoted practically all of my available time to water analyses since 1885.

My studies and experience include the proper interpretation of chemical and bacteriological analyses of water. I have installed at Beloit a private laboratory which is given up practically wholly to that study, and is known as the Beloit Sanitary Laboratory, where I have made about ten thousand analyses of water. In a lab-
6745 oratory used 1896-7 by me at Denver, Colo., we made in three years about six thousand analyses. I have studied the reports on Stream Examinations carefully. Am acquainted with the water course between Chicago and St. Louis; have made a trip by boat in daylight of the whole route. I have given special attention to the pathogenic bacteria known as typhoid, and have studied the water borne disease germs of typhoid and cholera.

6746 Bacillus prodigiosus described.

6747 It has been occasionally found in river water. Franklin speaks of finding it, and he mentions another case where it has been found. I found a form at Menominee which suggested it. I am acquainted with the experiment made by Dr. Ravold and as-
6748 sumed in the hypothetical question.

That experiment in my opinion does not possess value as touching the probable longevity of the typhoid bacillus. The longevity of the bacillus prodigiosus is not necessarily a measure of the

longevity of the typhoid bacillus and it does not contribute to the probability that a typhoid bacillus entering the drainage canal would find its way through, but on the contrary, it seems to be an improbability that it would.

I regard the experiment as a contribution to the study of self purification of that stream. It is an evidence for the stream being rid from them rather than anything else.

I have made a special study of the typhoid germ in connection with my other work, and they resemble the colon bacillus, which is a normal and constant inhabitant of the intestinal tract. The presence of the colon bacillus in water is very significant because the colon bacillus is the constant inhabitant of the intestinal tract of man and of the domestic animals, and being found in any amount of quantity or number in the water, it is a presumptive test that fecal matter as such finds its way into that water, and is one of the most important tests established in the determination of the sanitary quality of a water.

6751 The longevity of the typhoid bacillus in the human body, in soil, in water, in unsterilized water, and a comparison of labor-
6752 atory experiments with natural conditions.!

Experiments show they will not live as long in polluted water as in sterilized water. The organism in a polluted water is subject to certain enemies; it is subject to the toxins thrown off by the other forms and to the concentration of the toxins and the varying conditions of the stream.

I have read the experiment especially as conducted by Prof. Jordan and also the others, but his most minutely. I think I suggested the experiment myself first at the time of the conference. I am quite sure that I first suggested carrying it out and insisted upon its being done as a very important factor to determine the duration in life and the conditions met with in life. It was brought up the second day after we passed Peoria.

From my study of the Illinois River and my experiment it is my opinion that the viability or duration of life of the typhoid bacillus must be brief, surviving but two or three days; so far as those experiments show, not extending beyond that. It was recorded in the experiment that isolated cases were found as late as the ninth
6753 day, and out of some 1100 tests, if I recall just right, by Prof. Jordan, in only three of those was he able to note the presence of them. It seems that that experiment would tend to establish that the duration of life of the typhoid bacillus in the Illinois River must be brief; not more than three days or so.

I believe that to be largely due to the toxic effect of other organisms upon them. What contributes largely to their disappearance is that their enemies produce these results by the elimination of these toxins.

6754 I am acquainted with the Illinois River and the dams.

Bacteria will respond to the law of gravity in a running stream, and a comparison is made between the Illinois and the Platte River. When there is matter in suspension in a running stream it greatly assists sedimentation of bacteria; the bacteria tend to fasten

6755 upon these particles of suspended matter.

In my opinion the amount of water passing in the drainage canal could not produce the condition of clearness to preclude

6756 the possibility of the opportunity of sedimentation.

A discussion of dilution in connection with the problem of the self purification of streams, how it manifests itself. The diminishing of danger from infection and the effect of dilution of Chicago

6757 sewage with Lake Michigan water upon the conditions in the

6758 Illinois River as effecting the sanitary conditions of said river.

Physical conditions of the Illinois River compared with other rivers in the country for the purpose of purification and sedimentation.

The general principle, it seems to me, is that the lowlands

6759 along either side of the river are quite marked on the Illinois River as compared with others that I have followed along. Taking into consideration the physical surroundings, the study of the chemical analyses, the comparison of the bacterial analyses, the death rate of the typhoid bacillus, the rate of flow of the river, the Illinois River as discharged into the waters of the Mississippi, does not effect its quality as it passes along the State of Missouri. In fact, the data probably indicates that the Mississippi is not as good quality as the Illinois River itself in its lower reaches.

In my opinion it seems to me quite clear that there is no pollution dangerous to public health from the drainage canal which receives the outfall from the sewers of Chicago which reaches down the Illinois River as far as Grafton.

We have the agencies of dilution, the experimental work showing the life of the typhoid not exceeding three days, and the rate of

6760 flow of the river which shows that it exceeds considerably the life of these organisms; we have the study of the river from a chemical standpoint which shows the purification of the river, and we also have the data from the bacteriological investigations which show that the waters have purified themselves from a bacterial standpoint. That is, the water of the Illinois River at Grafton as evi-

denced by these data, appears to be of the quality of other rivers of this section.

To sum up these conclusions in my opinion the several agencies
6760 at work make the Illinois River at Grafton about a normal river water in this section.

It is my opinion that infectious matter coming from the sewers of Chicago do not reach as far down the river as Grafton for the reason I have already outlined.

Low water in the Missouri River at a time when there was high water in the Illinois River in my opinion would not enter it as a factor because the waters of the Illinois River have become purified through the process of self purification and have removed the infected
6761 or polluted matters, and, therefore, the condition of the Missouri River does not enter into this discussion.

6762 Prof. Sedgwick's question on low water in the Missouri River and high water in the Illinois answered.

In my opinion the sewage from Chicago does not affect the water supply of the City of St. Louis, or the waters of the Mississippi River as they pass along the shores of the state of Missouri.

From the experiments it is my opinion that typhoid bacilli passing from the sewers of Chicago in to the Chicago River and thence into the drainage canal, are destroyed in a short period, not exceeding more than three or four days after the passage into the Desplaines and Illinois Rivers. The experiment of Prof. Jordan and others has great value. It seems to show very clearly that typhoid bacilli will not exist in the waters of the Illinois for more than three or four days.

It sheds light upon the longevity of the bacillus in the sedi-
6763 ment of the polluted streams inferentially, and it is my opinion that the sediment of the streams polluted would not retain the bacilli for a period measurably longer than the polluted water itself. In pure distilled water the toxic effect of other bacteria would be entirely removed. In polluted water the toxins from organisms inimical to the typhoid bacillus would be operative, and to that principle I attribute the short duration of life of a typhoid bacillus
6763 in a polluted water.

Conditions that obtain in moist soil and in the sediment of
6764 a running stream differentiated, and the two conditions are not comparable.

Mr. Fuller's question on the comparison between the sediment of a running stream and moist soil, and the witness' answer to that question:

"I would say that I do not know of any demonstration of ty-

6765 phoid fever germ having lived for a period of one year in the sediment of a running stream."

In my opinion, from all the knowledge that I possess, the typhoid bacilli coming from the sewers of Chicago, could not traverse the distance to St. Louis and survive, and they could not possibly be a danger and a menace to the inhabitants of the state of Missouri using the water of the Mississippi for drinking and domestic purposes.

6766 The settling basins and a discussion of the same.

Epidemiology and the significance of the term.

6767 I have examined carefully the typhoid statistics of the Illinois, Mississippi and Missouri water sheds above St. Louis.

6768 The mortality percentage method contrasted with the rate per thousand.

Infection from rural population and its danger to water supplies discussed.

6769 Examples of epidemics caused by population pollution and discussion of the water supply of Denver, Colo.

6770 The position that bacteriologists and chemists occupy in Sani-
6671 tary Science.

Q. In the ascertainment of the quality of river water what aid is chemistry and bacteriology to a sanitarian in forming judgment as to the quality and potability of such water

A. In my opinion a sanitarian could hardly form a proper opinion regarding the quality of river water did he not have the chemical and bacteriological data upon which to base such an opinion.

6771 Citing the Platte River in Denver.

In studying the tables in Streams Examinations it is my opinion that the waters of the Illinois River begin to show a very decided purification at Ottawa which increases and reaches its maxi-
6772 mum at Averyville, which is above the city of Peoria. It receives at Peoria and Pekin a considerable addition of sewage material; another area or zone of purification commences at that point some distance, 30 miles or so, below, and is practically completed at Grafton, the river at that point appearing to be water of the quality of rivers in this section. In my judgment polluted and infected matters coming from the sewers of Chicago through the drainage canal would have become harmless before reaching Peoria, and would have been altered so that it would not be deposited on the bottom as sediment as infectious material. The bacteriological data already submitted in evidence, in my opinion and judgment, show the puri-

6773 fication of the stream before reaching Peoria, and it would be my opinion that sewage from the City of Chicago could not be a menace to the inhabitants of the State of Missouri and the citizens of the City of St. Louis using the Mississippi River water.

By comparisons of the data submitted by Professors Long, Palmer, Burrill and Jordan, it is my opinion that the Illinois River at Grafton discloses the least amount of impurity or pollution of the three rivers, the Illinois, Mississippi or Missouri.

It would be evident that if the Illinois River is of a better quality and does not show as much impurity as either of the other rivers, it would really benefit them, if anything, and in proportion as the waters become mixed. If the evidence should be that the Illinois River practically hugs the east shore and does not mix, particularly it would not affect them. If, on the other hand, the data
6774 should show that there is a great deal of mixing, then in pro-
6775 portion as this mixing occurs, to that degree it would improve, if anything.

MISSISSIPPI RIVER.

I have made a survey of the waters of the Mississippi River in the course of my professional work, and a study of the sanitary character of water supplies, the same extending over a period of at least
6775 12 years. The first place where I made an examination was
6777 at Brainard, Minn. It is located above St. Paul. The next
6778 point was Minneapolis; the next place St. Paul; Winona
6779 Dubuque, Ia., Clinton, Ia., Davenport, Ia., Rock Island, Ill., Muscatine, Ia., Burlington, Ia., Keokuk, Ia., Quincy, Ill. All
6780 of the above cities sewer into the Mississippi River.
6781 (Read from the record from pp. 6775 to 6782, which show the wonderful qualifications of the witness in regard to sanitary conditions of the Mississippi River.)

Q. From the examinations that you have made of the water of the Mississippi River from Brainard, Minn. on the north to Muscatine, Ia., on the south, what is your opinion as to whether the water of the Mississippi River is a suitable water in its raw state for drinking and domestic purposes?

A. From all the examination which I have made of the Mississippi River, from inspection at various points from Brainard and Minneapolis, Minnesota, to Quincy, Illinois, and from chemical and bacterial examinations from Brainard to Muscatine, Iowa, using these as the basis of the opinion, I am of the opinion that the Mississippi River water in its raw condition, unfiltered and not treated,

6783 is not a wholesome or safe water to use, nor one adapted for use as a public water supply, * * * and it is my opinion, therefore, that the mixing of the Illinois River with the Mississippi River, after it may have received the Missouri River, does not create any added danger to the inhabitants of St. Louis, or to the people of Missouri for public and domestic purposes.

It is my opinion that infective matter and pathogenic germs coming into the drainage canal from the sewers of Chicago, would not reach as far down the Illinois River as the City of Peoria, * * * and would not reach the intake tower of the St. Louis water-
6784 works at the chain of rocks in a dangerous state. And it is my opinion that the sewage of the City of Chicago entering the drainage canal, thence discharged into the Illinois River, which in turn empties into the Mississippi River, does not constitute a menace and a danger to the inhabitants of the State of Missouri or to the citizens of the City of St. Louis taking their water
6785 supply from the Mississippi River.

I do not believe that a germ of typhoid could lie in the bottom of the Illinois River for a period of from one to three years, and I know of no instance on record in literature that justifies such
6785 a conclusion.

An increased volume of water in the Illinois River and its
6787 effect upon the lowlands, and its consequent effect upon sedimentation.

The effect of the locks and dams of the Illinois River upon sedimentation, and the effect of the removal of these dams dis-
6788 cussed.

It is my opinion that prior to January, 1900, the water of the Mississippi River at the chain of rocks was not a safe and potable water, fitted for domestic and drinking purposes in its raw state, after the same had passed through the process of purification as adopted by the City of St. Louis in its settling basins, and neither was the water of the Missouri River a safe water for drinking and
6789 domestic purposes prior to January, 1900; neither was the
6790 Illinois.

I have done work on the Mississippi River at Omaha and Council Bluffs. I am of the opinion that the sewage discharged through the drainage canal has no material effect upon the water of the Mississippi and the Missouri Rivers at the chain of rocks. It is my opinion that the sewage as such does not reach the mouth of the Illinois River in an unchanged condition. The waters of the Mississippi and Missouri Rivers, excluding the waters of the Illinois River, in my

opinion, are not a safe water for domestic and drinking purposes, and are unsuitable to be used by the citizens of St. Louis in its raw state, and as treated by the City of St. Louis with the settling basins.

From the statistics of the continued prevalence of typhoid fever in the City of St. Louis, I am of the opinion that the present treatment of the water does not render the same safe and suitable water for domestic and drinking purposes to be used by the citizens
6792 of St. Louis.

Experience detailed in connection with filter plants at Denver, Colorado, Brooklyn, New York, Indianapolis, Indiana, Binghamton, New York, Portage, Wisconsin, Kankakee, Illinois, Stevens
6792 Point, Wisconsin, and Oshkosh.

Q. Has your business connection with filtering plants extended to the question of cost of filtration plants and the expense of operating the same?

A. I may say that I have never been called into consultation as to any filter plant where the question of cost of operating the same was not raised. In the matter of the installation of new plant and advising concerning them, the cost of installation and the cost of operating the same is one of the important questions always brought up for consideration, and upon which an opinion is expected.

From my studies of the sanitary qualities of the waters of the Mississippi River, I am decidedly of the opinion that the Mississippi River water in its raw condition is unfit for use for a safe and wholesome water supply without being subjected to processes of purification by filtration.

This conclusion is obtained through all my knowledge of the river, from personal study, and from chemical and bacteriological examination of the same, and that, too, not at a single point, but at different points in the river, reaching from Minneapolis, where its supply is taken from the river, and where I recommended extensive and efficient filtration of the water. The introduction of the Illinois River would not cause me to recede from that position, as, in my opinion, it does not materially affect the quality of the Mississippi River after the Missouri River is introduced into the Mississippi River. The known dirty condition of the water from the amount of silt and sediment which it carries, would, in my judgment, only make more desirable and more necessary the purification of the
6793 Mississippi at St. Louis by filtration.

In the event that a filter plant should be established at St. Louis for the purpose of filtering the water of the Mississippi River, which includes the combined waters of the Mississippi and Missouri

Rivers and the Illinois, from my knowledge of the Mississippi River as based upon personal investigations and chemical and bacteriological examinations of the same, and from my study of the analyses of the Illinois River at Grafton before the waters of the same are discharged into the Mississippi River water, I am very clearly of the opinion that the cost of purification of water below the mouth of the Illinois River would not be increased owing to the waters of the drainage canal finding access to the river, and, therefore, the cost of installation and operation of a filter plant at the City of St. Louis would not be increased owing to the admission of water from the
6794 drainage canal.

I am clearly of the opinion that the role which the drainage canal plays in the Illinois River would not affect the cost of installation, management or operation of a filter plant filtering the waters of the Mississippi River at St. Louis after the same have received the Illinois River at Grafton and the Missouri River at a point
6795 below.

I am clearly of the opinion that it would not cost any more to operate a filter plant or require more skill and expensive management of the same after the sewage of the City of Chicago has passed through the drainage canal into the Illinois River, and thence into the Mississippi River water above St. Louis than before the drainage canal was opened. I have made a table of averages based upon the analytical data presented in evidence in Streams' Examinations and Professor Long in the public reports of the Board of Health
6797 of the State of Illinois.

6798 Table of averages.

6799-6801 Explanation of the table.

In a word, the immediate effect brought out (by this table) is that the waters have undergone a practical degree of purification when they reach Grafton, and the analytical data clearly show that the water in 1900 was of a quality superior to that in 1899 for those dates given.

6802 Applying the same principle to the averages of the results of waters taken from the Mississippi River at Grafton, it is my opinion that the waters of the Illinois River at Grafton, as they empty into the Mississippi River, are better than the waters of the Mississippi River taken from the river at a point above Grafton.

Applying the same principle of interpretation of the analysis, it is my opinion that the waters of the Illinois, as delivered into the Mississippi River at Grafton, are of a quality upon these dates for which these averages are given, and they were the only dates from

which data were available which covered similar periods and similar seasonable fluctuations of the stream, and comparing these data, the waters of the Illinois, as delivered into the Mississippi at Grafton, are upon the whole a better water chemically for drinking and domestic purposes than the samples taken from the intake at St. Louis, the water of the intake at St. Louis being the waters of the Missis-
6802 sippi River after it has received the flow from the Illinois and
6803 Missouri Rivers.

I have studied the bacterial tables in Streams' Examinations
6803 and have prepared a table of averages.
6804 Table of averages.
6804-6805 Explanation of the table.

From a study of these tables, these tables being the results of the investigations of the samples of water on these different dates of the Illinois River at Grafton and the Mississippi River at Grafton, I am of the opinion that so far as the number of bacteria is concerned the waters of the Illinois River at Grafton are of a better quality than the waters of the Mississippi at Grafton.

6806-6807 Table prepared from Professor Jordan's bacteriological data in Streams' Examination.
6807 Explanation of table.

It is my opinion, therefore, that the bacterial condition of the waters of the Illinois River at Grafton, from such studies as this, is fairly comparable with the waters emptying into the stream at this season through the same period. It is better bacteriologically than the average of the waters of the Mississippi River taken at
6808 Grafton through this same period.
6809 A table of the bacterial flow of the Illinois River at Grafton with the flow of the Mississippi River at the same point and points below, as given in the table submitted by Professor Jordan, in the report of Streams' Examinations. Explanation of the table.

I find from the average of the counts of the bacteria for the first four months of 1900, which months, according to my study of the tables, represent the rivers in their worst condition, it is my opinion that the Illinois River, as indicated by these tables, is better in the number of bacteria contained in the same than the Mississippi River at Grafton or the Mississippi River at Alton, 100 feet from the Illinois River, or the Mississippi River at Alton, one-quarter distance from the Illinois shore, or the Mississippi River at Alton in midstream, or the Mississippi River one-quarter distance from the Missouri shore, or the Mississippi River at Alton 100 feet from the Missouri shore, or the Mississippi River at the chain of rocks 400 feet from the

Illinois shore, or the Mississippi River at the chain of rocks in mid-stream, the Mississippi River at the chain of rocks at the intake tower, the Mississippi River at the chain of rocks 400 feet from the Missouri shore and from Bellefontaine and West Alton, Missouri. This table indicates the much larger number of bacteria at these points than from the Illinois River at Grafton. This covering, as already stated, the first four months of 1900. Taken from the tables the
6810 river appears to be in its worst condition during the period which the tables cover.

I am verey clearly of the opinion that pollution and contamination from the sewers of Chicago * * * does not continue to be manifest and present as far down the Illinois River at Grafton, but, on the contrary, it seems to me that the combination of these agencies, all tending to practically purify the river so that sewage as such does not reach down the Illinois River as far as Grafton; and, further, the contamination and the pollution from the sewers of Chicago do not obtain in the Illinois River at Grafton and cannot be manifest and present from the Illinois River at the chain of rocks in the Mississippi. Acquaintanceship with the Illinois River at Peoria in 1892 and a comparison of conditions then with conditions that ob-
6811 tain in 1903.

I am of the opinion that the water supply of St. Louis is not contaminated, polluted or injured by the sewage of Chicago entering the drainage canal and thence into the Illinois River, * * * and hence the original organic matter of the sewage from Chicago does not find its way into the intake tower of the St. Louis water-
6813 works at the chain of rocks.

I am of the opinion that the Mississippi River at the intake tower of the St. Louis waterworks at the chain of rocks is not less valuable for drinking purposes, and it is not more liable to carry water borne diseases, such as typhoid fever and cholera, now, than
6814 it was before the sewage of the Sanitary District was run into it.

The effect of an increased speed in the current of the Illinois River in carrying typhoid germs down the river for a greater distance discussed, together with the subject of clearness and turbidity
6815 as affecting the sedimentation of bacteria.

6817 Professor Sedgwick's question on typhoid germs being depos-
6818 ited in the bed of Lake Peoria for a period of a month discussed.

As to whether typhoid fever could be deposited in Lake Peo-

6819 ria, being there in greater numbers than at the Bear Trap dam, discussed.

6821 The water of the Illinois River mixed with the water of the Mississippi and thence mixed with the waters of the Missouri is not a menace to the health of the inhabitants of Missouri living upon the Mississippi River, using Mississippi River water for drinking and domestic purposes at points on the Missouri shore.

Eliminating all other sources of infection save that from Chicago, I do not believe that typhoid fever germs from the Sanitary District can find their way to the water supply of the City of St. Louis through the intake at the chain of rocks.

Professor Sedgwick's question, wherein he assumes that typhoid fever germs pass from Chicago to the Mississippi River, thence

6825 into the intake, discussed and answered.

6825 Professor Sedgwick's question on the mere presence of pollution in water as affecting the longevity of typhoid germs, an-

6825 swered and discussed.

6825 Asiatic cholera.

Q. Does the presence of sewage in water add to the longevity or growth of germs?

A. From all the knowledge I have been able to gather by study upon this question, it is my opinion that the presence of sewage in water tends to diminish the viability of the typhoid bacillus.

6826 Questions based upon the increased population of the City of Chicago as affecting the water supply of the City of St. Louis, with the increased flow from the drainage canal, discussed.

Q. Taking into consideration all the assumptions assumed in the the last foregoing hypothetical question, and taking into consideration all the typhoid statistics as they obtain along the water sheds of the Mississippi, Missouri and Illinois Rivers, in the City of Chicago and in the City of St. Louis, and assuming that there is an increase of typhoid fever cases in the City of St. Louis since January, 1900, and taking into consideration all chemical, bacterial and other knowledge which you possess, what is your opinion as to whether the increase in typhoid fever, assuming that there has been an increase as above indicated in the City of St. Louis since the opening of the Chicago drainage canal, can be attributed to the opening of the drainage canal as a direct, immediate and approximate cause of such increase beyond all reasonable doubt?

A. From such study as I have given to the conditions stated in the assumption in your question, from my knowledge of the habits of the Mississippi River, it being in my judgment a water unfit to

use in its raw state for public water supply, in view of the fact of the pollution existing from the Missouri River, a matter as evidence already given in this case, from my knowledge of the conditions which obtain from the drainage canal and the Desplaines River and the Illinois River, and the agency of self-purification operative in this stream, all of these combined tending to affect a practical bacterial purification of the Illinois River at Averyville, I am of the opinion that any increase in typhoid fever, if there has been any increase of typhoid fever since the opening of the drainage canal, cannot be attributed beyond all reasonable doubt to the opening of the drainage canal as its direct, immediate and approximate cause.

Q. Assuming that there is an increase in the typhoid conditions in St. Louis over normal conditions, due to its water supply, where, in your opinion, should a sanitarian, studying the question, look for the causes of the infection?

A. For reasons which have been cited repeatedly in this examination, from knowledge of the Illinois River itself, its surroundings and the chemical and bacterial changes operative tending to the self-purification of the stream, and from the positive evidence of Professors Zeit, Jordan and Russell, proving that typhoid bacilli from the City of Chicago passing through the drainage canal and out in the Illinois River cannot exist in that river for a period exceeding more than three days or four days, it is my opinion that typhoid bacilli from the City of Chicago cannot find their way to the intake tower at the chain of rocks and the intake of the water works of St. Louis in the Mississippi River, and, therefore, the causes for such an increase in typhoid fever must be looked for at points nearer the
6828 intake tower than the Sanitary District of Chicago.

JACOB A. HARMAN.

DIRECT EXAMINATION,

By Mr. Todd.

Occupation, civil engineer; residence, Peoria; consulting engi-
6846 neer of the Illinois State Board of Health.

Illinois Valley and a description of the territory drained by the Illinois River as described in a report of the water re-
6847-6849 sources of Illinois by L. Everett.

Table of population, rural and urban, of the various sub-basins
6851 and tributaries of the Illinois River.

Table of rain precipitation on the Illinois River basin and
6853 tributaries.

Table of annual discharges for the Illinois River at Peoria
6856 covering the years 1890 to 1903.

Table of discharge of Illinois River at Peoria, Illinois, from
6857 1889 to 1900.

Table of discharges in cubic feet per second at Peoria, Illinois, for stages of two to twenty-two feet by 10th on gauge at
6858 Bridge street bridge, Peoria.

6859 Discharge diagram of the Illinois River at Peoria.

Table of discharges of the Illinois River as affected by its tributaries based on discharge measurements at Peoria and
6860 ratios of drainage areas.

6863 Sewage system of St. Charles, Missouri, described.

Letter of James P. Kirkwood, Esq., chief engineer of the Board of Water Commissioners of the City of St. Louis, dated December 11, 1865, on the subject of going to Europe and investigating filter plants in order to make a report as to the best methods
6866 of filtering the water of St. Louis.

ROBERT SPURR WESTON.

DIRECT EXAMINATION,

By Mr. Todd.

I am a graduate of Amherst College, in 1891. Was employed as a chemist for about three years with the American Sugar Refining Company and after that I was a student in the Institute of Technology, in the University of Berlin, and have been a volunteer worker in the laboratories of the Massachusetts and German Imperial Boards of Health. In 1895 I was connected with the Louisville water purification experiments and subsequently at West Superior and at Washington, District of Columbia, and at other places. In 1900 I was in direct charge of the water purification station at New Orleans and conducted an investigation lasting eight months as to the feasi-
6870 bility of purifying the Mississippi River water.

I am acquainted with the water shed of the Mississippi River above New Orleans. I have prepared a table of distances of the towns above New Orleans:

Baton Rouge,	132 miles.
Natchez,	265 miles.
Cairo,	965 miles.
Cincinnati,	1,415 miles.
St. Louis,	1,159 miles.

St. Paul, 1,823 miles.
Vicksburg, 366 miles.
Memphis, 735 miles.
Louisville, 1,305 miles.
Pittsburg, 1,875 miles.
6870 Mouth of the Missouri River, 1,165 miles.

The population on the water shed of the Mississippi in towns of 4,000 or more, including Chicago, for the year 1900 was about 9,000,000 people.

I have assumed that cities which have a population of 25,000 and over will discharge 175 gallons per capita of sewage per diem. I have assumed that the remainder of the urban population
6871 would produce 1,000 gallons per day per capita of sewage.

I estimated the amount of sewage from large cities, that is, cities about 25,000 population, to be 1,174,250,000 gallons per day. I estimate the amount of sewage from the remainder of the urban population, that is, the remainder of the population of cities from 4,000 to 25,000, to be 342,000,000 gallons per day, making a total of 1,516,250,000 gallons per day. This is equivalent to a flow
6872 of 2,310 cubic feet a second at New Orleans.

The dilution at New Orleans is as follows:

A. Maximum dilution, 1 of sewage to 586 of water; minimum, 1 of sewage to 83 of water. Average, 1 of sewage to 296 of water.

B. Expressed as cubic feet per second of sewage per 1,000 urban population, maximum, 150; minimum, 21; average, 75 cubic feet per second per 1,000 urban population for the year 1900.

C. As gallons of water per diem per capita of the urban population; maximum, 16,160; minimum, 2,262; average, 8,190.

While in New Orleans, I had the superintendence of the whole work. There was an advisory board of six engineers, of whom Mr. George W. Fuller of New York was the one with whom I came in direct contact. I was in charge of the water purification sta-
6873 tion in 1900 and 1901.

I had charge of the chemical and bacteriological analyses conducted at that station from November until the following September. Analyses were made daily at one point located in the Mississippi River and the results were published in the report of the water purification published in New Orleans in 1903 by the sewage and water board of New Orleans. I have prepared tables showing the composition
6874 of the Mississippi River at New Orleans.

Tables showing the composition of the Mississippi River at
6877 New Orleans.

The analyses show that apart from the nitrogen as nitrates and nitrites that the water is characteristic of the non-polluted water in this region. An abundance of oxygen is always present in the water, showing that the organic matter has been decomposed to about the limits. The number of bacteria is very low and is chiefly associated with the suspended matter. When the suspended matter is removed the water is of excellent quality.

Q. In the bacteriological determination of the water at New Orleans did you make any coli determinations during the course of this investigation?

A. Tests were made during the flood season, that is, from December, 1900, to April, 1901. These tests were made six times a week in December and the number of tests was gradually decreased in 1901 until April, 1901, when the tests were discontinued. Volumes varying from one cubic centimeter to 300 cubic centimeters were employed.

Bacillus coli was only found on three occasions during the five months of the tests. It was found during the first week of December, 1900. It was not found subsequent to that date.

When the bacilli were found in 1900 they were found in a small volume of water, namely, one cubic centimeter. The presence of these organisms in the water at this time and not at any other times is explained by the fact that on the banks of the river immediately above the intake of the water purification station a number of house boat men and squatters were quartered. During low water season these people had thrown their feces on the banks of the river and during the rise it is easy to account for the presence of the bacillus coli in the intake of the water purification stations at that time. Especially so, because the intake was located near the bank of the stream and suspended from a houseboat, but in comparatively shallow
6878 water.

Q. What conclusion did you arrive at from the results of these coli determinations?

A. That no unpurified sewage was present in the Mississippi River at New Orleans.

The discharge measurements of the Mississippi River at New Orleans are, maximum, 1,353,000 cubic feet per second; minimum. 191,000 cubic feet per second; average, about 685,000 cubic
6879 feet per second.

In my opinion there is not the slightest evidence that any unpurified sewage exists in the water at New Orleans apart from that small amount which may occasionally have been washed from the

banks of the stream outside of the levees and in the immediate vicinity of the water purification station intake during the time
6890 when the tests mentioned in your question were made.

CROSS-EXAMINATION,

By Mr. Jeffries.

Even though the City of Baton Rouge is situated 132 miles and within a thirty-three hour flow from the City of New Orleans, any sewage so discharged into the river from Baton Rouge has become purified within the time it reaches New Orleans within thirty-three hours. The facts are as I have stated them, that there are no bacterial evidences of sewage at New Orleans, in spite of the fact
6890 that sewage reaches the river.

TYPHOID FEVER DEATHS.

Tables.

Tables compiled from certified copies of the reports of the different boards of health reports of cities upon the Illinois, Mississippi and Missouri water sheds and the City of St. Louis and the City of Chicago, tabulated by the years.

Deaths reported from typhoid fever in cities lying tributary
6901 to the Missouri.

Deaths reported from typhoid fever in cities lying tributary to the Illinois River, exclusive of Chicago.

Deaths reported from typhoid fever in cities lying tributary to
6902 the Mississippi River above St. Louis.

Total number of deaths reported from typhoid fever in cities lying tributary to the Mississippi, Missouri and Illinois Rivers, respectively.

6903 Deaths in Chicago and St. Louis.

W. P. MASON.

DIRECT EXAMINATION,

By Mr. Todd.

I have been professor of chemistry in Rensselaer Polytechnic Institute of Troy, New York, for twenty years. Have made a special study of water analyses in the examination of potable water, especially for city supply, and have had experience in the interpretation of chemical analyses and have made a study of sanitary problems. I

am the author of a book on water supply and as an expert have reported and testified in cases in different towns and cities throughout the United States. I have examined the water supplies of Paris.

Hamburg, Copenhagen, London, Liverpool, Hague, Stuttgart,
6904-6905 Lubeck, Amsterdam and sundry others.

6906 Description of the different places in Europe visited.

Am acquainted with epidemics both in America and in Europe, and am familiar with the literature. Have investigated epidemics of typhoid in America and have made a study of Asiatic
6906 cholera in Sicily and Italy and more particularly at Macena. Results of investigations of Asiatic cholera in Macena, Sicily.

Am acquainted with the water course between Chicago and
6907 St. Louis, have made a trip over it.

Am acquainted with Dr. Ravold's experiments and my opinion is that in view of the large number of the bacillus prodigiosus introduced and the small number found, the results of that experiment show a very considerable death rate of the bacillus prodigiosus, and by inference at least as large a death rate of the bacillus of
6909 typhoid fever under the same circumstances.

Have made a special study of the typhoid germ and it is closely related to the colon bacillus.

The character of the water affects the longevity of the typhoid bacillus. In the case of a relatively pure water the longevity of the typhoid bacillus is greater than where it has to fight for existence the saprophytic bacteria.

I am acquainted with milk epidemics. There are a great many epidemics from British sources as reported by Hart. Laboratory experiments are more favorable for the longevity of the typhoid than conditions of nature.

I will quote in support of that position some experiments that have been recently made upon the bacillus coli communis by the Massachusetts Board of Health, where the vessel containing the germs suspended in the Merrimac River was a large one, about twelve feet deep. Under those circumstances it was found that the longevity of the colon bacillus was limited to eleven days. The germ of typhoid will not live as long in polluted water as in pure sterilized water. It has to struggle for its existence amid adverse germs in great numbers and it is overgrown and the bacteria are producing
6911 toxins which are capable of interfering with its growth.

Sedimentation in the Illinois River affected by high and low
6913 water disclosed.

Causes that compel bacteria to settle to the bottom of a flowing
6914 stream.

The effect of increased volume of flow in the canal, with the added sewage of an increased population, as affecting the sedi-
6914-6915 mentation in the Illinois River.

Sanitary significance of dilution in considering the process of
6915 the problem of self-purification of streams.

The greater the dilution the less the danger from infection. The addition of Lake Michigan water to the sewage of Chicago is a benefit to the sanitary condition of the Illinois River, considered from the standpoint of dilution alone.

Physical conditions of the Illinois River compared with other rivers in the country for the purpose of purification and sedi-
6919 mentation.

My opinion is that the waters of the Illinois River do not have any appreciable effect, good or bad, upon the waters of the Mississippi River into which they flow, although it is possible it may slightly improve the mixture, inasmuch as, if there is any difference between the Illinois River at Grafton and the Mississippi River at Grafton, and the Missouri River above the junction, that difference is in favor of the Illinois River at Grafton. At the same time I do not think there is very much choice. I believe the typhoid bacilli passing from the sewers of Chicago would die in the Illinois River, or, to put it differently, would die before Grafton was reached. I am now speaking about the great mass of them. It is possible that some resistant germs might make the journey, but the great mass of bacilli of
6917 typhoid fever would perish before the Mississippi was reached.

As to the time that a typhoid bacillus will live in moist soil and in the sediment of a running stream, I do not think the conditions would be parallel or comparable, and the fact that a typhoid bacillus lives for several months in moist soil does not justify the assumption that it would live the same length of time in the sediment of a river, and I do not know of any experiment that has demon-
6919 strated that fact.

My opinion is that typhoid bacilli coming from the sewers of Chicago would not be a danger and a menace to the inhabitants of St. Louis using the waters of the Mississippi for drinking and
6921 domestic purposes.

TYPHOID STATISTICS.

I have examined the typhoid statistics on the water sheds above St. Louis, together with the typhoid deaths in St. Louis and Chicago.

I notice that Chicago is quite variable. Beginning with 1899 it is 442, and then dropping instead of increasing, as St. Louis does, 1900, the deaths being 339, rising again for 1901 and 1902 to 509 and 801 and dropping off again in 1903 to 588. I notice, as already stated, that whereas the St. Louis rates uniformly increase the Chicago rates go up and down in a variable fashion. These statistics are for entire years as given. The relation between Chicago and St. Louis in the matter of deaths from reported typhoid would be better found in statistics per month and I am prepared to show the statistics per
6922 month in graphic form if the counsel so desire.

The typhoid mortality method and the rate per 10,000 dis-
6923-6924 closed.

I will repeat that the percentage method is not the commoner one in use, although it is used, the more common method of stating it being the determination of number of deaths from typhoid for
6925 100,000 people.

CHARTS.

Deaths from typhoid fever as reported in Chicago and St.
6926 Louis, official health reports for 1900, 1901, 1902 and 1903.
6928-6931 Explanation of the charts.

Q. Professor, from your examination of the monthly mortality from typhoid in the City of St. Louis and in the City of Chicago for the years 1900, 1901, 1902 and 1903, what conclusion do you draw as a sanitarian and epidemiologist as to the cause of typhoid fever conditions in the City of St. Louis being attributable to typhoid conditions that exist in the City of Chicago?

A. From an examination of the charts just presented I am of the opinion that no relation whatever exists between the typhoid fever as represented in Chicago and as represented in the City of St. Louis. In other words, I am strongly convinced that typhoid fever in St. Louis is not produced by typhoid fever in Chicago. It will be seen from an examination of those charts that the characteristics of typhoid fever are far from being parallel for the two cities. In many instances the rise of the curve from Chicago is co-incident with the falling of the curve for St. Louis, particularly so for the month of August, 1902, when the typhoid in Chicago grows from 44 to 193
6931-6932 and the typhoid in St. Louis drops from 26 to 21.

Chart prepared by W. P. Mason, based on Professor Jordan's
6933 colon determination for 1901.
6934 Explanation of the chart.

Judging from the bacillus coli communis contents of the sev-

eral waters operating upon one cubic centimeter as stated, the relative purity of the waters would stand, first in purity, Illinois River at Grafton; second, Mississippi River at Grafton; third, Illinois River at Averyville; fourth, Missouri River at Bellefontaine; fifth, Mississippi River water at the St. Louis intake, and, sixth, the Illinois River at Pekin. Basing upon the same data from the several waters taken at the chain of rocks the relative degrees of purity would stand: Most pure water from the Illinois shore, next in purity from the mid-stream, next in purity from the intake tower, and last in purity from the Missouri shore.

Q. How does the Missouri River at Bellefontaine and the Mississippi River at Grafton and the Illinois River at Grafton compare as to the purity of pollution?

A. Basing my reply upon the bacillus coli communis contents
6935 they compare as follows:

The Illinois shore at Grafton is the most pure, the Mississippi River at Grafton is next, and the Missouri River at Bellefontaine is the least pure.

6936 Typhoid epidemic caused from rural population.

Q. When considering questions regarding typhoid fever, do you regard it as important to note the interval of time elapsing between effects of water supply and the drinking of infected water?

A. I regard that as very important. That is a topic upon which I have pretty strong opinions, and upon which I have quite an amount of data. I have made analyses of 205 British epidemics reported by Hart. * * * In thirty-three epidemics due to stream and reservoir water I found the death rate was 9.85 per cent. of the cases. In seventy-five epidemics due to well water, I found that the death rate was 11.83 per cent. of the cases, and I found that in twenty epidemics due to milk the death rate was 12,79 per cent. of the cases, showing that a well water epidemic was distinctly more serious in character than an epidemic caused by water which had carried the typhoid germs some distance from the point of infection to the point where the water was used for purposes of drinking. I made an examination of 357 cases of typhoid fever at Waterville. Some of these cases used the city water supply, which was from a contaminated stream. Some used well water where the wells were contaminated. Some used both sources of water. I found that among the cases that used city water only 41.41 were severe. Among those cases not using city water I found that 61.29 were severe, thus showing that the typhoid produced by city water was a milder type, and my explanation of that is that the typhoid germ having to struggle for existence in

a river under adverse circumstances, when it arrives at a point where the water is drunk, is not capable of producing so much poisonous material, or, in other words, not capable of producing a severe case of fever, if it produced one at all. In the opinion of Mr. George C. Whipple, he makes use of the expression, "immediate pollution is very much more dangerous than remote pollution," a view which
6936-6937 is entirely in accord with my views.

WELLS.

Taking all the assumptions stated in the question (assuming 4,846 wells in the St. Louis, etc.), I believe that the water of those wells was responsible for a portion of the typhoid fever in St. Louis, because I am a great believer in greater danger coming from a polluted well water than from the water of a polluted stream. My reasons are based upon all data such as that which I gave in answer to a previous question showing that the death rate of well water epidemics was greater than that of stream epidemics, and showing that the intensity of fever from well water epidemics was greater than from stream epidemics. My opinion is that given points nearer and more remote from St. Louis intake, said points being located upon a water-course flowing thereto and said points all possessing typhoid in
6938 their sewer discharges, I would consider the danger of typhoid in St. Louis greater from the nearer points than from those more remote.

I do not think a typhoid bacillus lying in the sediment of a stream for sixty days would produce typhoid fever, nor that they would be able to retain their dangerous qualities after such a discharge in the bottom of the river. It do not think that the sewage from Chicago, passing down the Illinois River at different sea-
6939 sons of the year, or at different stages of the river, would be a danger and a menace to the citizens of St. Louis using the water in question.

The emptying of the Illinois River into the Mississippi River makes no material change in the character of the combined waters. What little change there is is an improvement, and the mixture of the Illinois with the Mississippi and Missouri does not create any added danger to the already polluted and contaminated waters of the Missouri and Mississippi River below Grafton, and consequently is not a menace and a danger to the inhabitants of the State of Mis-
6941 souri using the water for drinking purposes. My opinion is that the water supply of St. Louis taken from the intake tower is not contaminated by the sewage of Chicago.

6942 The effect of dams in the Illinois River discussed.

Dams have the effect of improving typhoid death rates in cities, and the conditions at Pittsburg are cited.

I do not regard the Illinois and Mississippi or Missouri rivers,
6943 prior to January, 1900, as a safe drinking water for domestic purposes.

The sanitary condition of the waters of the Illinois at Grafton, in my opinion, has been improved since the opening of the drainage canal. They are rather better than those other rivers, although, as I have stated twice before, there is very little difference between them. In my opinion the water of the Mississippi and Mis-
6944 souri, exclusive of the waters of the Illinois, are not a safe and suitable water for use by the citizens of St. Louis in its raw state.

6946-47 Prof. Sedgwick's question on sewage polluted streams extending the life of the typhoid germ and the accumulations of typhoid at Lake Peoria discussed.

DETROIT EPIDEMIC.

Q. Are you acquainted with the Detroit epidemic?

A. To the extent that I have had information appertaining thereto given to me by Prof. Williams, who has testified in this case. He gave it to me at the time that he was collecting it. I
6948 talked the matter over with him, and it seemed to me that there might be some doubt with reference to the connection between typhoid fever in Detroit and the dredging of the Black River.

I have no knowledge of the presence of infected Chicago sewage in the Illinois River at Grafton, and I believe that the use of the water of the Mississippi at the Chain of Rocks, because of the
6949 admixture of water from the Illinois River, would not be a menace to the health of the inhabitants of St. Louis.

Assuming that there was no typhoid pollution in the waters of the Mississippi and its tributaries above the intake of the St. Louis waterworks other than that derived from the sanitary district of Chicago, I believe that typhoid germs are not liable to find their way into the water through the intake tower at the chain of rocks and become a danger and a menace to the inhabitants of the City of St. Louis.

Prof. Sedgwick's question in regard to assuming typhoid fever to pass from Chicago to St. Louis is answered by Prof. Mason as follows:

"I do not know of any analyses or experiments that justify such an assumption, but, on the contrary, I am of the opinion that the charts which I have offered in evidence show that there is no connection between typhoid fever in the City of St. Louis and the City of Chicago, and were it liable that typhoid germs should pass into the water at the intake I should expect that the curves of typhoid fever in St. Louis and in Chicago would show parellelism,
6950-51 whereas they show quite the reverse.

Assuming there has been an increase of typhoid fever in St. Louis since 1900, I would attribute any increase to infection from nearer points because of what I have already testified to as my belief that the nearer the point of infection the greater the danger, and because further, that the charts which I have offered in evidence show that there is no relation between typhoid fever in Chicago and
6951 typhoid fever in St. Louis.

Assuming that the question means that the opening of the drainage canal constitutes an immediate and continuous danger under all existing conditions to the inhabitants of St. Louis on the Missouri shore, I shall repeat that in my opinion it does not. * * *
6952 Prof. Sedgwick's question and answer on the mere presence of pollution discussed.

The presence of sewage in water, in my opinion, does not add to the longevity of the typhoid germ.

6954 CHOLERA DISCUSSED.

I believe that the increase of typhoid fever, if there is an increase of typhoid fever in St. Louis, is not due to the opening of the drainage canal. It should be attributed either to an entirely
6955 local cause, such as that of well water or milk supply, or else to a river carrying infection from points nearer at hand.

FILTRATION.

Sedimentation should be supplemented by filtration. In this opinion I entirely concur with what has been stated by Messrs. Hazen and Fuller in a report on the water supply of the City of St. Louis,
5956 dated 1902, which report is set out.

My opinion is that the addition of Chicago sewage by the drainage canal to the system of the Illinois River would not add any additional expense to the purification of the Mississippi water by filtration at the chain of rocks. The installation and opera-

6957 tion of the plant would not be greater in point of expense by the addition of the Chicago sewage as it now is added to the system of the Illinois River.

CROSS-EXAMINATION,

By Mr. Jeffries.

My opinion is that in consideration of the facts regarding the Chicago sewage being dumped into the Illinois River, as at present, and the facts concerning the condition of the Illinois River that the germs of typhoid coming from Chicago sewers would be de-
6960 stroyed en masse by the time the mouth of the Illinois was reached, although some resistent organisms might go beyond that point, such as organisms, however, representing a small number and, in my opinion, low vitality.

Some typhoid fever germs from some typhoid fever patients are possessed of greater vitality than the germs from other typhoid fever patients. For the same reason that a crop of turnips growing
6961 upon a good soil would be better than one growing upon a poor one.

Q. May it not be true that these specially resistent typhoid fever cells, and the especially resistent cells of all pathogenic bacteria, are in reality the ones that produce disease?

A. In my opinion is that those specially resistent cells at their point of departure from the human body are fully as capable or even more fully capable of producing disease than the greater numbers of their less resistent brethren with whom they started upon their journey after leaving the body. Whether they arrive after the interval that may be chosen for the period of investigation in a condition to produce disease may be open to question, because the mere
6961 fact of their being resistent enough to arrive living does not mean that they will have enough toxin producing powers left to form that serious poison which may cause disease.

RUDOLPH HERING.

DIRECT EXAMINATION,

By Mr. Todd.

6975 Hydraulic and Sanitary Engineer, New York City. Associated in business with George W. Fuller.

I took the course in civil engineering in Dresden, Germany, in

6976 '67. Experience and qualifications in this country and in Europe.

Was on the commission which made the report advocating the
6979 building of the drainage canal in connection with Benezette Williams and Artingstall.

6980-90 Preliminary report.

6993 Question of dilution discussed.

6995 Table showing the calculated composition of sewage of different degrees of dilution in a running stream.

6997 Table of dilution of the sanitary canal based on population and flow for 1900 and 1901 and 1902.

The table indicates that the mean discharge during each of the three years was above the line which limits the offensive dilution, therefore indicating that there should be no offense.

I have investigated the question of sewage disposals in Europe and in this country since the filing of the preliminary report. I have had fifty cases of sewage disposals under consideration myself, and I have examined the principal European works every time I have
6999 been there, which has been three or four times since then.

In considering the several possible ways of disposing of the sewage of Chicago from present knowledge and experience, my recommendation to-day would be that the sewage of Chicago should be disposed of by dilution through the channel, substantially like
7000 that which has been constructed with its subsequent discharge in the Desplaines and Illinois rivers.

Chart entitled "Sanitary District of Chicago Schematic," rep-
7001 resentation of the self-purification of the waters of the Mississippi, Missouri and Illinois rivers.

7002 Explanation of the chart.

From an inspection of the diagram it will appear that Chicago is situated, so far as the average flow of water is concerned, about 18½ days from St. Louis, Kansas City on the Missouri about 6¾ days, Omaha about 11.6 days from St. Louis. On the Mississippi River Minneapolis and St. Paul are situated about 15 days from St. Louis, on the same basis. The conclusion of the chart, as indicated by the ordinate at St. Louis, is that the relative proportion of typhoid bacilli arriving at St. Louis from the population situated on the Illinois, the Missouri and the Mississippi rivers between the limits of Chicago, Omaha and Minneapolis, are about as 13 to 96 to 107, respectively. These figures are merely the proportions. They indicate the relative frequency of the still virulent typhoid bacillus at St. Louis, arriving there from various cities on these three rivers,

7003 based on the population of the cities, and also based on the examinations made by Hiram F. Mills as to the longevity of the typhoid bacillus.

Prior to 1900 I do not consider the Illinois, Mississippi or Missouri rivers a safe drinking water. The water at St. Louis should be artificially purified by filtration.

7004 I am acquainted with the report made by Benezette Williams, Wisner and Allen Hazen, in which my associate, Mr. George W. Fuller, was asked to consider these features, and he made a report, which is added to the report of the commissioner. My personal views are that this water, in order to be supplied to the City of St. Louis for domestic consumption, should be purified by mechanical or rapid filtration, as the best, most rational and least expensive method of purifying this particular water. I have had considerable experience and taken interest in the matter of filtration. I first visited European filters in 1881. I was acquainted with Mr. Hyatt, who invented the first rapid or mechanical filter, and introduced the same in this country, and always anticipated some advantage to be gained from such a method of filtration, and have followed the advance of mechanical filtration ever since. I studied the methods of slow filtration in the ordinary European method and in connection with the water supplies of Philadelphia and New York, in both of which cases I recommended the slow sand filtration for adoption. I was asked to pass upon the methods to be adopted at Washington, D. C., in connection with Mr. George W. Fuller and Mr. A. Hazen. I am acquainted with the cost of building filters and of operating filter plants. In my opinion

7006 it would make no particular difference in the construction method or cost, nor in the method or cost of operation to filter the water of the Mississippi with the Illinois eliminated than it would with the Illinois containing the sewage of Chicago.

Q. Taking the data which you have introduced in evidence, what help would that data be to you in considering such a problem?

A. This data would indicate to me that first and foremost a filtration of the water was necessary, due to the probability that typhoid bacilli would reach St. Louis from the Mississippi and Missouri, and to a less extent from the Illinois River.

Q. What consideration would you give to the sewage coming from Chicago?

A. I should give no consideration at all because it was a small factor in the problem. It was too small a factor in the problem to materially affect any consideration.

Q. In the operation of such a filter plant that would be e-

tablished to meet the demands of the people of St. Louis for a pure and safe water-supply would the operation of such a plant require a higher degree of skill or more expensive men to manage and operate such a plant with the sewage of Chicago emptying into the
7007 Illinois River than it would if such sewage was not present in the Illinois River through the drainage canal?

A. It would not.

(Witness temporarily withdrawn.)

ALBERT S. CRANE.

DIRECT EXAMINATION,

By Mr. Todd.

Civil engineer, graduate of Cornell University. Traveled in 1891 with Mr. Hering in Europe, visiting sewage purification and water filtration works. Chief engineer of the Michigan and Lake Superior Power Company at Sault Ste. Marie, and principal assistant
7008 engineer of the Sanitary District of Chicago.

I prepared the chart introduced in evidence by Mr. Hering, based upon the life of the typhoid bacillus as found by experiments made by Hiram F. Mills. The data for the profile including the Missouri, Mississippi and Illinois rivers were taken from a paper published by the Department of the Interior, entitled "Water Supply and Irrigation Papers of the U. S. Geological Survey, Number 44." Also from a report of L. E. Cooley, entitled "Waterway of the Lake to the Gulf." The distance there given from St. Louis to the mouth of the Illinois River was 38 miles; from the mouth of the Illinois River to the upper dam at Joliet is 325 miles; and from dam number 1 at Joliet to Lake Michigan 38.6 miles. The figures on the horizon line represent days' time of the flow of water from
7009 the various towns to St. Louis.

In the case of the Illinois River, they were obtained from actual float experiments made during the summer of 1903, under the direction of Mr. Randolph. The minimum time flow was taken as .8 of the mean. Fifteen days was the quickest time that we could get that float down. We call that 18¾ days, or, in other words, the actual time was divided by .8. The reason for that is that it is generally considered to be the relation between maximum velocity and mean velocity in an open stream. Prony was the first man that gave that. It is generally conceded by engineers. The time for the Missouri and Mississippi rivers was computed. First the mean discharges

of these two streams was obtained on the Mississippi River at Grafton and the Missouri River at St. Louis, being 57,000 and 127,000 cubic feet per second, respectively. The data were obtained by using the reports of the Mississippi River Commission, entitled "Tabulated results of the discharge measurements of the Mississippi River and its tributaries and outlets for the years 1838 to 1898, and plotting this to form a discharge curve." The average gauge readings at Grafton were taken for the years 1890 to 1894, inclusive, and then for
7010 the Missouri River the years 1895 to 1899, inclusive. After these average stages were obtained the average discharge was obtained directly from the curve.

7011 Approximate discharge curves based upon discharge measurements made by the Mississippi River Commission, 1838 to 1898.

In the chart introduced by Mr. Hering, the results at St. Louis were so arranged that the results of the Illinois River were placed opposite the combined results of the Missouri and Mississippi rivers, so that they might be directly compared. This would show that the Illinois River has the effect of a city of 13,000 situated immediately above St. Louis, the Missouri River of a city of 96,000 and the Mississippi River of a city of 107,000, or a relationship of 13 to 96 and 107.

CROSS-EXAMINATION,

By Mr. Jeffries.

7013 The distance, according to Mr. Cooley, between Lake Michigan and St. Louis is 364.7 miles.

7014 Populations of towns on the Illinois, Mississippi and Missouri rivers included in the charts.

Assuming that the flow from Chicago to St. Louis was ten
7016 days, it would have the effect of a town of about 160,000 located upon the Mississippi River immediately above the City of St. Louis.

RE-DIRECT EXAMINATION,

By Mr. Todd.

In maximum flood times the time of flow from Kansas City
7018 being three days instead of 6.8 days, the effect of the cities on the Missouri River would be that of a city of 230,000 directly above St. Louis.

RUDOLPH HERING.

CROSS-EXAMINATION,

By Mr. Jeffries.

The real object of this drainage canal was and is to remove the sewage material from the Chicago River in order to prevent deleterious substances getting into the lake.

I reported upon the disposal of the sewage of Chicago by
7020 other methods which were known to accomplish a proper purification or inoffensive disposal of the sewage.

7021 Another method was the pumping or removal of the sewage from the city upon land adjacent to the City of Chicago.

There is a current in Lake Michigan along the west shore near
7024 the City of Chicago almost at all times. The velocity at times is observed to be as much as two and three feet per second, but generally, of course, less.

When I entered into the study of this case the best information that I was familiar with regarding the longevity of the typhoid bacillus, which is the most important one to consider in cases of this kind, was that contained in the reports of the Massachusetts State Board of Health, which I used in preparing the chart entitled "Sanitary District of Chicago, schematic representation of the self-purification of the waters of the Missouri, Mississippi and Illinois rivers between the cities cited." Since having been engaged in the case, I have become acquainted with similar investigations which have recently been made by witnesses in this case, which information is much more exact and practicable and in accordance with actual facts, in my opinion, than the Massachusetts experiments. Had I asked this diagram or this chart to be prepared later, I should have used the later and better information contained in the recent testimony in this case.

As applicable to the typhoid bacillus, my opinion is that particu-
7027 larly with reference to this case the experiments made by Doctors Russell, Jordan, Zeit would guide my opinion in this question.

Q. Would you consider the water stated in the last question as being free from typhoid bacilli from the city mentioned in that question which contained 1,600,000 people?

A. As a sanitary engineer I would not be able to answer that question because I would have to take this information from somebody else. I would further say that if there was an absolute guarantee that a water-supply was free from all disease germs I would

then state that so far as the water pollution was concerned I should not insist upon filtration, but we are not sure that many disease germs, including typhoid, are not carried by the winds, by air, by insects. In fact, we know that they are so carried, therefore, as in the recent status of an important case, although the evidence indicated an almost impossible pollution by typhoid bacilli, I should still insist that the water be filtered as a safeguard to public health.

A sanitary engineer is employed for the practical purpose of carrying out sanitary works with the funds of the people. The engineer is a medium between the sanitarians and the money of the people. He must advise a work which is reasonable, economical and at the same time guard the people against all reasonable dangers in a sanitary way. His judgment, therefore, must be independent, and he takes into consideration all the work done by the chemist and bacteriologist and weighs this evidence in the light of the financial condition of the city which employs him and makes that recommendation which in his opinion is best under the circumstances.

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I do not know of a case where the water of a running stream has been recommended as free from typhoid bacilli without filtration.

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In the construction of a filtration plant I always take into consideration the sources of pollution, of infection, and have in some instances made what is called a sanitary water survey of the entire water-shed.

The running of a filter plant, like the running of any plant, can be somewhat variable owing to the fact that human beings are required to take care of the management. When there exists a special danger threatening a community extra precautions are taken to avoid anticipated possible trouble. It is quite natural, therefore, and if I give the orders myself. If a known epidemic exists there should be every reasonable precaution taken for special care to be exercised during that period.

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There are not infrequent filter plants where the bacterial results give a removal of 100 per cent. of the bacteria. It has been found in Europe as well as in this country that after the introduction of filter plants the typhoid fever rates has dropped generally about one-fourth of the rate that previously existed.

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In highly polluted and infected water I should prefer the slow filters to the rapid filters, for the reason that the chance for infection passing the slow filter would be very much reduced as compared with the rapid filter.

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The cost of a slow or rapid filtration plant is about the same. By adding the interest on the investment to the cost of operating expenses the two methods cost very nearly the same, but in some
7032 instances, where sand in large quantities is not readily available, the mechanical or rapid method is usually found more economical.

7033 Reference to the filter plants at Hamburg and Altoona and the excellent results obtained by filtration.

The effect of a city of 13,000 inhabitants immediately above St. Louis has upon the sanitary condition of the water that as an engineer I am not able to tell you what such effect would be. I would get such information, if I wanted it, myself from others especially qualified to know what such effect would be. As a sanitary engineer, and taking into consideration what I could learn from others
7036 regarding the question of effect, I would state that under the conditions assumed that it would make no difference with me in my recommendations regarding a plant to be considered for St. Louis.

The cost of carrying the sewage to Joliet and establishing a
7040 purification plant there could possibly be done, but it would represent an investment of nearly 80,000,000 of dollars.

RE-DIRECT EXAMINATION.

By Mr. Todd.

Q. In the operation of a filter, what relationship does the bacteria bear to matters in suspension?

A. In very turbid waters, such as the Missouri, it has been found that the chief [illegible] of the engineer is to remove the turbidity, that is the suspended matter, in the water. It has been found that if a very turbid water is thoroughly clarified that incidentally thereto the bacteria are also removed, and therefore, if we give consideration in the construction of works to the economy and complete removal of the suspended matter which caused the turbidity we accomplish all that is desired, even to the removal of the bacteria and in including the disease bacteria, judging from the effects of such filters upon the occurrence of such germs.

Q. Is there any validity to the assumption that a city of 13,000 inhabitants exists upon the Mississippi River immediately above St. Louis, based upon the chart which you have introduced in evidence?

A. The information which the chart was intended to convey, in my opinion, was the relative amount of infection that would be contained in the three rivers upon reaching St. Louis, irrespective of

any population residing immediately above St. Louis, and this relationship is expressed by the numbers 13, 96, 107 for the three
7043 rivers, respectively.

GEORGE DOCK.

DIRECT EXAMINATION,

By Mr. Todd.

I am a physician and teacher of medicine and have the Chair of Theory and Practice of Medicine in the University of Michigan. This is my thirteenth year in that institution. I graduated at the University of Pennsylvania; spent a year in a hospital at Philadelphia in the worst typhoid fever district in Philadelphia, in Kensington, in the capacity of interne. After that I went to Germany to prose-
7044 cute my studies. I went to Leipsic and paid a great deal of attention to typhoid there. From there I went to Berlin, studied bacteriology, and spent two years over there. I attended the University of Leipsic, Berlin, Vienna and the Pathological Institute in Frankfort. Upon returning I went back to Philadelphia, where I was assistant to Dr. Osler and Dr. Musser in the University Hospital, and there I began the study of malaria. Dr. Osler was then the first man in America studying malaria. Spent a great deal of time working on malaria in the practical diagnosis of the disease. Afterward I went to Galveston to teach medicine and pathology. On account of my interest in malaria I went there and stayed three years as professor in the Galveston Medical School and physician to the hospital connected with the school.

In Galveston I found they were diagnosing practically no typhoid fever at all. I saw lots of typhoid fever patients there. I was able to see that cases that were being diagnosed as malaria and typho-malaria were typhoid fever, and my experience showed me that none of these cases had malaria. I did, however, see fatal cases of
7045 malaria. They were cases that came from the tropics, Nicaragua or Panama, or else cases from the interior of Texas, where they occasionally have very severe forms of malaria.

I became very much interested in the practical diagnosis of so-called malarial diseases, continued malaria and various local names that are given to this disease.

On one occasion I made an offer to visit any patient having typho-malaria or continued malaria, and examine the blood free in order to settle whether it was malarial fever or could be diagnosed

as typhoid. I never had occasion to have my offer accepted. I saw many cases and examined them all very thoroughly; read several papers on that subject and have been quite widely quoted, and became looked upon as somewhat of an expert in malarial diseases.

From Galveston I went to Ann Arbor, and there I had the same experience I had in the South. I found that the doctors were diagnosing many cases of typho-malaria fever. I examined many of those cases post-mortem as well as in life, and I was able to show the same thing, that cases that were diagnosed as typho-malaria and continued malaria were all cases of typhoid fever. In Michigan I did not see any fatal cases of malaria at all. I have cases sent in under the diagnosis of typho-malaria, or some similar name, and I have frequent occasion to clear up the diagnosis.

The Mississippi Valley is, of course, a great point in both of
7046 these diseases, and in studying the features of typhoid fever and malaria I studied the conditions and talked with many doctors throughout there, and when I lived in Galveston I always came through St. Louis two or three times a year, and usually stayed there a day, and had opportunity for looking around the town from a malarial standpoint; that is with the eye of a malaria searcher. I was looking for malaria everywhere. I have given attention to malaria in St. Louis. I examined the outskirts of the city and formed the opinion that I have, which was not based upon examinations of my own of patients, but I had some correspondence with doctors in St. Louis, because I was writing on malaria, and the doctors there
7047 wrote me as to their methods of examination and various questions connected with malaria, and I gathered some information that enabled me to form an idea on evidence that we could not see with our own eyes.

I have read the literature on the subject and have read a number of articles in the medical journals. I might mention an article by Dr. Bremer, a well known physician of St. Louis, and I have the article with me in a medical journal known as the Medical Review, published in St. Louis, and the number I think is the number of August, 1895. Dr. Bremer states: "In our part of the country, and probably throughout the larger part of the United States, physicians are apt even to-day to look upon ailments as due to malaria which in reality have nothing to do with this disease, either directly or indirectly." There is a footnote to this, as follows: "This means St. Louis and environments in particular, and the Mississippi Valley in general, but it probably applies to the whole United States."

In another place he states as follows: "Periodic chills followed

by high temperature which mark the initial stage of so many cases, are generally interpreted as due to malaria, hence the erroneous and mischievous diagnosis malaria, remittent or typho-malaria, under which names so many cases of typhoid figure in the reports of our State Board of Health."

7048 Also the following: "How a practical question, to what extent does malaria exist in our part of the country (the Mississippi Valley), basing my opinion on the examination of about five hundred individual cases of all sorts of individuals, I have come to the conclusion that in our city at least malaria is an extremely rare disease, so rare indeed is this disease, at least in its pronounced forms, that when about four years ago I went to the City Hospital for

7049 a number of months in the hope of finding a good plasmodium infected subject my efforts were unsuccessful for a long time. The cases pointed out to me by attending physicians as malaria and treated as such proved to be infections which had nothing in common with that disease."

I may say that this bears out the experience I have had myself in various places having the general climatic conditions of St. Louis in mind, and especially with the experience I had in 1898 in some of the army camps.

I was asked by Surgeon-General Sternberg of the United States Army at that time to visit certain army camps in order to examine the blood of the patients diagnosed largely as malaria. In accordance with that I examined the Sternberg General Hospital at Chickamauga, the hospital at Knoxville and at Camp Meade, Pennsylvania. At that time most of the cases of typhoid in the army camps were diagnosed malaria. In the Sternberg Hospital, for example, there were four hundred patients when I got there, and practically all of them had a diagnosis of malaria in one form or another, typho-malaria, bilious remittent, or some such name. I examined most of these patients individually. I examined their blood and examined their clinical features, with the result that I found only one out of the whole four hundred had malaria fever.

I also made some autopsies on patients dying with so-called malaria fever, and found that they had typhoid fever without malarial.

Then I went to Camp Meade, where the conditions were practically the same. Eighty per cent. of all the fever cases had a diagnosis at their bedside of malarial fever with various modifications. In a few days those diagnoses were changed just around, 80 per cent. typhoid and 20 per cent. malaria. I examined all the suspected cases and found only one patient out of several hundred that really had

malaria. The disease was in practically all the cases typhoid. At Knoxville I was not able to find any malarial cases. I reported this matter to the surgeon-general, but my report has not yet been published.

I have made a special study of typhoid fever for about twenty years; have made several hundred autopsies on patients who died of typhoid fever, not all of them my own patients however, and on a great many patients diagnosed as either having typhoid fever
7050 or having some other disease. In such cases the diagnoses were often wrong. From such experience I have seen a good deal of typhoid fever. I have made a special study of the so-called germ diseases, and they came intimately within the scope of my experience. I have studied typhoid fever and malaria fever from the standpoint of a bacteriologist and clinician.

Typhoid fever defined with its clinical diagnosis, intermittent,
7052 remittent, typho-malaria (the word typho-malaria is also used as a cover for diagnostic difficulties), congestive fever, simple continued fever.

Remittent, intermittent, typho-malaria, congestive and simple continued fevers are not distinct types of disease, and so recognized by bacteriologists and clinicians. Usually all such names are included by careful boards of health under the heading of typhoid fever, and, as I have just said, they usually refer to typhoid fever. My own experience with them among doctors and in the hospitals and in the post-mortem room is that they are applied to typhoid fever in a majority of cases. An examination of the blood of malarial organs on one hand, or the typhoid reaction on the other, usually clears them up very quickly.

Assuming the number of deaths reported under the head of typhoid fever in St. Louis in the Board of Health statistics, as contained in the hypothetical question, the figures show an increase during the last ten years, but not a great increase; the increase for the last five or even six years from 1895 to 1903 is a steady and gradual increase. There is no one point there where one can see a certain increase out of proportion to the general line.

7054 I am particularly struck by this increase since 1898, because in 1898 the doctors all over the country had their attention very strongly called to the wrong diagnoses that were formerly made of the so-called typhoid diseases, and the attention of the public has been very strongly called to it. As shown in the army camps especially, that soldiers were dying of typhoid that were supposed to have malaria. The people found out it was possible to make a more correct

diagnosis, and doctors, in my experience in various parts of the country, have been more careful in their diagnoses since 1898, and while it was an increase, I would not call it a great or a certain increase.

The number of deaths reported as occurring from typhoid fever alone in the City of St. Louis does not, in my opinion, properly represent the total number of deaths actually occurring in that city from typhoid fever. The most important reason is that the death rate from malarial diseases is altogether too high, too high for every year. Take an exceptional year for typhoid when there was an accidental condition; the malaria there is 50 per cent. higher than it was two years before. In 1890 there were 226 cases of the malarial disease.

I include all these various diseases in malaria; in 1892 there
7056 were 326 cases. Now, from studying malaria very carefully at that time, I say there was no reason why malaria should increase in a city like St. Louis to that extent at that time. The death rate every year is altogether too high, and is higher than I believe possible.

Malarial fever described, with the different types of malaria.

The intermittent form of malaria is common in the Central States of the Mississippi Valley, and that form of malaria is never fatal; nobody ever dies of it unless he has had some previously
7057 existing fevers. The reasons why doctors employ these terms are various. In the first place, very often the doctor has an incomplete idea of the diagnosis of typhoid fever; that is, his idea of typhoid fever is not correct. He does not use the proper method of diagnosis. Very often it is done for what might be termed business or social reasons. The doctor does not like to give out the impression that his town has a lot of typhoid fever in it, and may often have an intimation from the health authorities not to give it out. In the army camps surgeons were frequently ordered by superior officers not to make out a diagnosis of typhoid fever. The diagnosis of typhoid fever is always very unpopular. They fall back on some other word, especially typho-malaria. Cities that are going to have world's fairs in them always object to having such a name used.

From the statistics that I have been furnished and from my
7058 experience in the diagnosis of typhoid fever and typho-malaria fever I should say it would be impossible to say exactly how many cases in the typho-malarial list should be classified as typhoid fever, but anywhere between fifty and ninety per cent. of the so-called ought to be called typhoid; at least fifty and probably as many as ninety. For a city like St. Louis a death rate of two or three per cent. from malaria fever would be very high. No cities in this

country have actual statistics on malaria. The best places to get statistics are in hospitals where they pay special attention to malaria, and the experience in a hospital like the Johns Hopkins Hospital, where they have climatic conditions rather more favorable for malaria than those of St. Louis, might be taken. In ten years
7059 they were able to get only three deaths from malaria fever; that is practically nothing at all in comparison to what St. Louis has in one year. It is generally recognized and most careful boards of health refuse to accept such classification because all such diseases should be put in the typhoid table. The Board of Health of Michigan, for instance, orders that all typho-malaria be classified under typhoid, and the new classification recommended by the United States census makes the same recommendation.

After considering the typhoid death rate and the typho-malarial death rate by the month for the City of St. Louis from 1895 to 1903, the chief conclusion I draw is, to conform to what I said before as to statistics regarding malarial diseases, that they are not altogether faulty. It comes out more clearly when we study the reports of malarial diseases by months, where the death rate is altogether impossible for malaria in the latitude of St. Louis. For example, the typhoid deaths reported for the months including January, February, March and April nobody dies of malarial fever in that latitude in those months. Further, malarial fever cannot occur then, even in such a malarial country as the Philippines malaria does not kill all the year round. In several months corresponding to our winter season they do not have any deaths from malarial fever. A study of this table would be enough to show that the whole malarial statistics of that town are seriously faulty.

7061 The added totals of typhoid fever and typho-malaria do not indicate a marked increase in typhoid fever; however, they indicate a slight and gradual increase from the year 1898, an increase that I would explain partly from the fact that the diagnosis of typhoid fever has become broader all over the country, more cases are [illegible] included. There is a tendency everywhere to increase the proportion of typhoid cases in that way. There has been a slight and gradual increase. By combining the two groups the increase is not as great as the increase under typhoid fever deaths reported in the Board of Health reports. There is nothing in the statistics to show that an explosion of typhoid fever occurs. The increase, for example, is slightly more marked for the year 1901, but even there is is not at all striking; it is not such a thing as we find, for example, in the case of Butler, Pennsylvania, or in the case of Cornell College, in the town of Ithaca.

In regard to the circular letter sent out by the Board of Health of St. Louis I think the sending out of such a letter would explain the rise as it occurred in the last five years. Of course, we have to stick to the last two years on account of the letter, but the increase is not so great as one might expect. Such an order calling attention of physicians to the law requiring them to report all cases of typhoid has been carried out in other cities, and the increase has always been marked; I mean has been distinct. Here there is an increase too, but it does not strike me as being very much greater than it was in the three years before.

The typho-malaria fever goes down as one might expect. Doctors having their attention called by the notification would report
7063 more cases as typhoid and less as typho-malaria than they would before.

My opinion is that the two tables, taken separately, do not correctly show the typhoid condition, for the reasons, I think, I have mentioned before. The safest way would be to look upon all those anomalous fevers as typhoid.

Assuming the combination of the two tables and the population of St. Louis according to the United States census reports, and the intervening years estimated by Farr's formula, the table does not show that there has been a marked increase. On the contrary, a slight increase, such an increase as I would ascribe rather to increased
7064 care in diagnosis rather than to any outside condition.

The figures are compatible with such slight increase as we
7065 find here, and typhoid fever in most places, like most other diseases, runs cyclicly without any fresh conditions from the outside, or any marked condition in the matter of water supply or drainage. I should think there would have been conditions at St. Louis which would have increased the typhoid incidents. The fact that many people were going there, people not accustomed to the climate, perhaps living carelessly. In nearly all such times we see such epidemics break out.

One of the most serious sources of typhoid fever where they have surface drainage and wells both, the conditions are especially dangerous. In cities that have a good water supply, and still have wells, they always have a distinct amount of typhoid fever. The wells in small cities and in rural districts are very serious causes of typhoid fever. The number of wells in St. Louis would be a very serious source of typhoid fever.

7066 From a consideration of the statistics and the typhoid condition in the City of St. Louis, my opinion is that the increase

indicates rather a change in the conditions of the City of St. Louis itself rather than in the main water supply. Supposing that the main water supply comes from a river; a change in the condition of the river water is always indicated in such cases by a marked increase. As to such an increase as we have here it is altogether compatible with changing local conditions, such as wells and the ordinary course of typhoid epidemics.

CROSS-EXAMINATION,

By Mr. Jeffries.

7067 Dr. Blickhahn of St. Louis wrote me after he had been working on malarial fever for two years that he had never been able to see a certain form of malarial organism called the crescent. I was rather surprised at that, because I would have rather supposed that he would find crescents in St. Louis. Crescents are found in more severe forms of malaria fever. Dr. Blickhahn wrote me he had not been able to find any, and asked me to send him one of my specimens. I sent him some specimens that I had brought from Texas. I supposed he had simply overlooked them, but he wrote back and said he had really not seen them up to that time. That was additional evidence that severe forms did not occur frequently

7068 there, although, of course, they might occur now and then. That was in 1903 and 1904.

Q. What fevers known as fevers which would produce death may in a sense be associated with typhoid fevers?

A. In this country there are practically none, especially in

7069 the northern latitudes.

Q. From your examination of the malarial records of St. Louis you have arrived at the conclusio that physicians of that city are not competent to make determinations as to the character of the disease?

A. I would not say that all the physicians, but I have already put myself on record as saying that a large number of the physicians are not making a correct diagnosis of this disease, and I have

7070 no hesitation in repeating it here.

Q. And you have expressed that opinion altogether from the record?

A. Partly from the record and partly from the facts bearing upon the occurrence of this disease, and partly from my experience in certain definite places where I have investigated the actual cases, and partly by becoming familiar with a good many doctors from all over the country.

In the army camps, for example, I saw doctors from every state and saw how they made their diagnosis, and I was able to see
7071 that a large majority of them were making faulty ones, and I was able to demonstrate that they were.

RE-DIRECT EXAMINATION,

By Mr. Todd.

7077 Q. Doctor, in figuring out the percentage of increase, assuming that the average for 1895-6-7-8 of the percentages for the four years before 1900 was 21.05, and for the four years subsequent 36.5, and that the difference between these averages was 15.45, if figuring out the percentages by dividing 15.45 by 21.05 gives a percentage of practically 73 per cent. does that 73 per cent., in your opinion, figured upon the basis that I have indicated in arriving at it, express a large increase in typhoid fever?

A. No, but I should say that I consider that method of getting at the result very faulty. For example, the increase did not occur in a single year, but was spread over a series of years, and it is not a figure that varies at a point in those years, but goes up steadily. If the 73 per cent. had occurred between 1899 and 1900 I should say that there must have been a new focus of infection, or else that the old focus of infection must have been extremely badly handled, but as it is spread over four years and the ascent is gradual and really began a year before the point of deviation, I still adhere to my former statement that it is not a great increase.

Q. In figuring out the per cent of increase, does the average
7078 give as correct an idea as to the relationship existing between each year?

A. No, the per cent for periods of time is an artificial one. There might be local conditions in any one year that would offset the average too much. In all such statistics there is a very serious error depending upon the comparatively limited number of cases that we have to deal with, so that the difference in any one year would offset the average too much, so that I always work those things out on scales, because the scale, taken year by year, gives a better idea
7079 of the course of the disease than a bunch of years even reduced to a scale.

RE-CROSS EXAMINATION,

By Mr. Jeffries.

7079 Q. I will ask you if the result shown on this table for the four years from 1896 to 1899 does not show that there was an

alternate increase and decrease, year by year, in this, to wit: 1896, 20.2; 1897, 23.4; 1898, 17.3; 1899, 23.3, and that since 1899, to wit, the years 1900 to 1903, inclusive, that there has been a continued increase?

A. That is right.

RE-DIRECT EXAMINATION,

By Mr. Todd.

Q. If the percentage of increase in 1899 over 1898 was 34.7, in 1900 over 1899 was 25.3, in 1901 over 1900 was 14.7, in 1902 over 1901 was 9.5, and in 1903 over 1902 was 23.7, would the fact that the Exposition of St. Louis was going on in these years in any measure account for the difference in the increase of 1903 over 1902?

MR. JEFFRIES: I object to the question for the reason that it calls for an answer impeaching the testimony of this witness in his direct examination, in which he stated that it was a fact, and it is conceded by counsel to be a fact, that enterprises such as
7080 World's Fairs have the effect to cause physicians to fail to report typhoid fever as typhoid, and causes them to report it in some other column.

7081 MR. TODD: In view of counsel's explanation I will not press the matter.

7082 LEWILLYS F. BARKER.

DIRECT EXAMINATION,

By Mr. Todd.

I am a professor in the University of Chicago. I have been a professor in that university for a little more than three years. Was formerly in charge of the department of anatomy pending the establishment of a research department of internal medicine. I was associated nine years with the medical faculty of Johns Hopkins University at Baltimore. I was assistant to Prof. Wm. Osler for one year, and for two years I was a fellow in pathology and bacteriology with Prof. Welch, and was appointed to an associateship in anatomy with Professor Mall. My last period in Baltimore I was made associate professor of pathology with Dr. Welch at Johns Hopkins.

I graduated from the University of Toronto and served one year in the hospital in Toronto. I spent some time in the University of Leipsic, and was away from Baltimore on several commissions.
7083 The first commission was one established by the Board of Health of Maryland. Dr. Flexner and I were sent to the

Loona County Valley to study an epidemic of a peculiar disease which turned out to be an epidemic of cerebral spinal meningitis. In 1899 the Johns Hopkins University sent Dr. Flexner and myself as a special commission to study the tropical diseases in the Philippines, and incidentally to study the epidemics of plague and beri beri in Hong Kong, India and Japan. In Japan we were fortunate enough to visit Gute's Laboratory, and met there Shiga, who worked out the bacillus of acute dysentery in Japan. In Manilla we had an opportunity of studying an epidemic of 200 cases of beri beri at Cavite.

7085 Description of beri beri.

When we were at Hong Kong we were permitted to make autopsies on cases of plague and also bacteriological studies of cases of plague, but we had a far better opportunity in India, where we saw 800 cases of plague in one day at Poona. The main benefit of the trip in India was to see a really great epidemic, which was the first great epidemic we had ever seen; 800 cases every day,

7086 with a patient coming in at the front door every eight minutes and a dead one being carried out the back door every ten minutes.

The first year I came to Chicago I was appointed by the Secretary of the Treasury in Washington, along with Professor Flexner of the University of Pennsylvania and Professor Novy of the University of Michigan, to proceed to San Francisco to investigate the disease prevalent there among the Chinese, and to ascertain whether or not it was Bubonic plague. An extensive report was made to the surgeon-general of the Marine Hospital Service in the Department of the Treasury establishing the existence of the plague in San Francisco. We saw several cases of the disease during our visit, and made pathological and bacteriological and animal experiments, and proved absolutely that the disease was Bubonic plague. The other epidemics I have investigated were in Baltimore.

During the whole nine years I was there I had an opportunity of studying the epidemics of typhoid that existed in that city. Typhoid is quite prevalent at various times of the year, especially in the spring and autumn, as was also malaria in Baltimore, so that I had an opportunity of there becoming very familiar with both diseases. I had an opportunity of investigating to the extent of one giving all his time to scientific work in a pathological line, and an investigation of cases coming into autopsies and coming into the wards of the hospital which was given over largely to research. I have made a special study of typhoid fever and its causes.

Typhoid fever may be contracted through the drinking of pol-

luted water or of infected food, or through the contact with the fingers of other objects contaminated with typhoid bacilli. There is a great deal of evidence that flies can carry typhoid bacilli from
7088 one place to another, such as the experiment of Dr. Alice Hamilton.

Remittent, inter-mittent, typho-malaria, congestive and simple continued fevers are all clinical rather than pathological terms, and date back to the time when classification had to be made on symptomology rather than upon pathology and etiology. None of these terms would be used by a skilled clinician.

I have made a special study of fevers in so far as a man work-
7090 ing in internal medicine a large part of his time and in pathology must make a study of fevers.

7091 I have examined the statistics of typhoid fever in the City of St. Louis as given by the health reports of St. Louis under the heading typhoid fever, and also those under the heading remittent, inter-mittent, etc., and the typhoid death rate in St. Louis as estimated from the official reports.

7092 Tables of typhoid and typho-malaria.

I have for comparison the reports of deaths from Baltimore
7093 during four or five years under these two similar groups of diseases.

7093 The reports of deaths in Baltimore.

Those reports are sent in by physicians to the Board of Health as deaths from those causes, and the Board of Health cannot very well do anything but tabulate them in that way.

Of course, from what I have said it is clear that in my opinion those cases are nearly all cases of something else, cases of some disease that could be diagnosed by skilled physicians—mostly typhoid—and some of them perhaps acute tuberculosis, but chiefly typhoid. In fact, I think the addition of the two columns, one-half column to the remittent, inter-mittent, etc., fevers, would give a truer typhoid death rate in the City of St. Louis than any other of the statistics that we could get. I think that the majority of those under the head of remittent, etc., if examined carefully by skilled clinicians, would be definitely diagnosed as specific disease which we know about.

There are many reasons for confusion of diagnoses in dealing with this disease, especially where men are not trained in the most modern method of diagnosis where it would be extremely difficult for a practitioner who has not been trained in the recognition of the malaria parasite to decide between many cases of malaria and many cases of typhoid. It would be extremely difficult for a man who is

not familiar with the modern agglutinative and bacteriologic test to distinguish between many cases of typhoid fever and cases that are not typhoid but resemble it.

The most important clinical test we have for typhoid fever, though no one test is sufficient in my opinion to rely upon always in a diagnosis of typhoid, is the Widal reaction or agglutinative test. More important still is the symptom complex along with the presence of the Widal reaction.

Q. In view of these facts as you have related them, does it appear from the figures given in the report of the St. Louis Health Department that there has been an increase of typhoid fever in the years 1900 to 1902, inclusive, as compared with the ten preceding years in the City of St. Louis?

A. It is absolutely certain if these statistics are reliable that there has been no increase. The statistics show that the total number of deaths from typhoid and the intermittent group together run along at a tolerably constant figure. The figures, however, in the typhoid fever column alone, an increase in the number of typhoid deaths, quite a marked increase during the last three years, of from 1900 to 1902; they also show quite a marked diminution in the remittent group during the last three years. There has evidently been simply a transfer from the remittent column to the typhoid column. In other words, typhoid fever has been diagnosed more often during the last three years than it has in the last preceding years. There has been no greater number of cases, but the diagnoses have been better. That the diagnosis is not yet good by many of the physicians in St. Louis is evidenced from the large number of cases still reported in the intermittent group. When I say cases here I mean deaths every time, and I have no doubt that the discrepancy of cases already existing would be infinitely greater than the death report shown with the exception of obvious epidemic years of typhoid from 1890 to
7096 1899; the death rate varies between 95 and 215, and there are two years with 106 and 107 deaths from typhoid.

In 1900 the deaths from typhoid were 168; 1901, 198, and 1902, 222, and whereas in the remittent group the least number of deaths before the year 1900 in the group is 134, the highest number of deaths being in the epidemic typhoid year, 326, just where we would expect it to be, but in 1900 these numbers drop away down to 112 for 1900 and to 80 for 1901, almost one-half what it was in any year preceding 1900, and in 1902 102. The whole number, however, for the whole ten years runs along in a fairly constant way. The total number of the two groups added together run along in a fairly

constant way, indicating clearly to one who is familiar with the way these deaths are diagnosed that there has been a transfer during the last three years from the remittent group to the typhoid group. A transfer which is most commendable, because it shows that a more correct diagnosis has been made of typhoid fever during the last two or three years, but that there are far too many cases reported by physicians of St. Louis as remittent, etc., fevers, is clearly shown by comparison with the Baltimore typhoid death rate. The conditions of the two cities are not dissimilar, and typhoid and malaria exist in all probability in about the same proportion in the two cities, but whereas in Baltimore the typhoid fever is very much more abundant as compared with the remittent group, the explanation in my opinion

7097 is that the typhoid fever is better diagnosed in Baltimore than in St. Louis, and that is not surprising, because very important studies have been made during the last ten years in Baltimore on typhoid and malaria, perhaps the most important in the country, and the city is being repeatedly filled with young practitioners who have been trained under the men who have made these special investigations in typhoid and malaria, and nearly all of the young men who go into practice in Baltimore from the Johns Hopkins University have skill in making the diagnosis between the two diseases, so that I feel sure that there are still a large number of cases in this city being put in the wrong list; that physicians are not yet diagnosing typhoid fever as they ought to.

Q. From your investigations and consideration of the vital statistics of the City of St. Louis, has there been an increase, in your opinion, in the typhoid death rate since 1900 over the death rate that existed in St. Louis for a period of five years prior thereto?

A. No. There has not been an increase. The letter from the Board of Health in 1899 to the practitioners of St. Louis, I think, had an influence for this reason, that it is not an uncommon practice among physicians to designate cases that they regard as typhoid fever itself as remittent, or continued, or typho-malaria, or malaria fever, for the express reason of not exciting too much the fears of their patients. I know that that has been done by physicians. Patients are afraid of typhoid fever, and they naturally beg of their physicians to tell them what the disease is. The best clinicians avoid the

7098 term of typho-malaria altogether.

The death rate in St. Louis is not excessive as compared with Baltimore and corresponding cities. I have compared it with figures from Philadelphia, Boston, New York, and especially as compared with Philadelphia the figures in St. Louis are very moderate.

I am in a general way acquainted with epidemics caused by water borne diseases such as typhoid, and the distance that the contagion of typhoid has been shown to travel in a flowing stream, if one takes the extreme statement of one investigator, the maximum distance is about seventy or seventy-five miles. That view and assertion has not
7099 met with general acceptance, however.

I am acquainted with the general conditions which obtain from Chicago to St. Louis. I have given the subject of bacteriology considerable study, and have taught it in Baltimore, but no special study since I came to Chicago. I am acquainted with the life of the typhoid bacillus. I have worked a great deal with it myself, and I am more or less familiar with what has been written about it.

In my opinion it would be harmless after living in the sedi-
7100 ment of a stream for a period in excess of fifty days.

In my opinion typhoid bacilli would not be able to survive the journey from Chicago to St. Louis and be a danger and a
7101 menace to the inhabitants of the City of St. Louis, the germs coming from Chicago.

7102 In my opinion there is no evidence in the literature which would make it seem probable that typhoid bacilli could go from Chicago to St. Louis and enter the intake to the St. Louis water supply and cause typhoid fever; all the evidence that I know would oppose the probability or possibility of that occurring, and, moreover, the proof that it did occur could not be brought unless every typhoid bacillus now entering the stream between, say Lockport and St. Louis, could be excluded from the river. In my opinion typhoid bacilli would not survive the journey.

The sewage from Chicago is not a menace to the inhabitants of the City of St. Louis, in my opinion.

In my opinion there would be two main factors that would lead to the death of the typhoid bacillus in river water, the oxidation that occurs along with sedimentation and the unfavorable food relations—three factors—and the third perhaps the most important of all, the influence of saprophytic bacteria in the stream.

The introduction of the mass of organic material from the stock yards and distilleries of Peoria, in my opinion, would favor the disappearance of the germs.

The only possible relation that I can see between the figures on typhoid fever and related diseases in the St. Louis health reports and the opening of the Chicago drainage canal is the difference in diagnosis during the years mentioned as concerning these two groups, the typhoid fever and the remittent group. So far as the total number

of deaths in those two series is concerned, I can see no connection between the opening of the drainage canal and the figures. In my opinion the life of the typhoid fever bacillus introduced into
7103 the drainage canal would be from five to seven days.

The death rate from typhoid fever in St. Louis does not indicate an excessively polluted water supply as compared with the water supply of many American cities, but is excessive as compared with ideal conditions. The death rate in St. Louis is lower than in a number of American cities, if you mean by the term "well protected" what is ordinarily meant by that term in this country.

In my opinion, assuming the typhoid conditions and all other
7104 conditions on the Illinois, Mississippi and Missouri rivers, the cause of typhoid fever in the City of St. Louis could not be attributed to the sewage of Chicago.

7105-6-7 Tables of typhoid statistics upon the three water sheds.

In my opinion the probability of infection or pollution of the water supply of St. Louis, assuming all the conditions upon the water sheds above St. Louis would be largest from those places within the mean flow of five to seven days—I don't know how to express that—from those places where the average flow or the main flow is within five to seven days of St. Louis. I think the probability of in-
7108 fection or pollution from the great distance requiring more than twelve days for example, would be remote.

CROSS-EXAMINATION

By Mr. Jeffries.

7112 Examination of the water supply of Baltimore with regard to causing an epidemic, and the personal investigations made of the same.

7118 Examination in regard to conditions at Toronto and the means of getting a good water supply for the city.

7123 Q. What is the evidence with reference to the longevity of pathogenic germs?

A. Well, I should refer you to the quickest way to get at the evidence, Baumgarten's Jahreskricht.

7123 I have worked with the typhoid bacillus. I have made no special experiment dealing with the longevity, but I have
7124 worked with typhoid bacillus and had it die out on me in media. When I speak of the longevity of typhoid germs and apply
7124 their longevity to the waters of the Illinois, I borrow the experience of other men. I am very glad to acknowledge that, as everything else that I have not worked on myself.

Q. And your attention and work there were directed entirely to the treatment of the disease?

A. No, indeed, largely to the diagnosis, the symptomology,
7125 the clinical history and course and the post-mortem appearance.

I am familiar with a large part of the work that has been done
7126 along those lines, and have to be as a clinician has to be familiar with the mode of the spread to be a scientific clinician.

Q. And you obtained that by reading the publications of men who have studied it?

A. As every other scientific man does, yes, sir.

Q. Including the literature on the longevity of the typhoid
7126 germs?

A. Yes, sir, I have read the literature of them.

Q. Then, Doctor, not having made an examination or a study, either of the literature or from practical experience of the life of the typhoid fever germ in river water, how can you express an opinion and confine your opinion as to the life of the typhoid fever germ to from five to seven days in river water?

A. For two very good reasons: One, that I have read of the life of bacteria, many of which are more resistant than the typhoid bacilli, and environmental descriptive influences, and the other that I have talked with many men and bacteriologists in whom I have confidence who have worked directly upon this problem, and they have given me the results of their experience in conversation.

Q. So you mean to express an opinion that is neither based upon a study of the literature or writings of men who have made it a study, nor based upon practical experience, but based ab-
7128 solutely upon what people have told you with reference to it?

A. I do, and I am very glad to do it, because I don't think I
7129 could give you a more reliable source.

I classify myself as a pathologist in the sense in which the term has been used in this examination to-day. My answer would be that one gets after years of work with bacteria and diseases, and after years of perusal of the literature, a capacity for passing judgment upon labor and experiments and influences that does permit him to come to a conclusion just as satisfactory as any one can get under the circumstances.

7132 I said that I thought that in all probability any sewage typhoid bacilli would largely die out before ten days.

Evidence is in favor of the view that the greater the dilution with pure water the longer the life of the typhoid bacillus, and the greater

the mixture of sewage the greater the percentage of sewage, the greater the number of saprophytic bacteria present the quicker
7135 the typhoid bacillus dies out, other things being equal.

Q. Now, it is your opinion, is it, that the sewage material kills the typhoid bacillus?

A. My opinion is that they die out quicker when there is a great deal of sewage than where there is not; this is rather different from the way you put it. I am not sure that any typhoid germs get as far as Grafton from Chicago. I don't think that they do. I don't think that anybody could say that they did not; my opinion is that they do not.

The reason for their death is, in my opinion, sedimentation and oxidation processes, together with the influences of saprophytic bacteria and exhaustion of food supply, are the most important factors.

I don't think they would disappear so fast in the winter on ac-
7145 count of the saprophytic growth. In my opinion, the evidence favors the view that typhoid germs die out in the course of sedimentation. The fact that we have great typhoid epidemics and that they disappear and die out again, the stream does purify itself. We have typhoid epidemics even from pond water, and they die out; if they didn't die out and all the people who are susceptible had not been infected, then the typhoid bacilli would have caused so
7149 many more people to have the disease that it would not have died out.

I do not think that the sewage of Chicago would have any effect on the water at Kampsville, because there is so much sewage in the water just below Chicago that I think the water would be
7151 robbed of its dangers very quickly.

Q. Would you recommend the water in the Illinois River at Henry as an epidemiologist for domestic purposes?

A. No, nor anywhere else in the Illinois River. I should
7154 not recommend it without filtration, nor any river water.

Q. In the absence, now, of any biological test, we are talking about the river itself, with your knowledge of epidemiology?

A. I think it would be safe.

Q. Would you recommend it?

A. No.

Q. Would you recommend it at Grafton?

A. No. Nor at New Orleans. In the absence of all contaminations on the way I think it would be safe, but I would not recommend it at St. Louis, although I think it would be safe, because we

have ways of making absolutely sure. My opinion on safety
7155 is an opinion. We have methods of being absolutely sure about our drinking water.

Q. Have you not stated that the sewage of Chicago has no effect upon the water at Grafton?

A. I said in my opinion it had not, but I did not recommend its use. I said in my opinion it would have very little effect,
7157 but that is a very different thing from recommending its use. If there were no typhoid in Averyville among people who were
7161 drinking the water of the Illinois I would recommend it. I regard the biological test as the most important, and that is just the reason why I have been insisting on the biological as the most important one all through, for that reason. We can state when the disease germ will disappear, because there is no evidence
7163 of any typhoid infection being carried by water further than seventy-five miles, so far as I know.

I did not know that Professor Sedgwick had made the state-
7164 ment that a typhoid germ has been carried 175 miles, from Cumberland to Washington, and I am surprised that so eminent and accurate a man as he should do so.

In my opinion, the presence of ten typhoid cases at Peoria would be more dangerous for the river water at Pekin than the presence of ten thousand cases of typhoid in Chicago. I would advise boiling the water at Grafton. I think it would be safe, but I
7167 would boil it until we had more knowledge about it. I always use the most perfect method whenever I can in technique.

I think typhoid fever would die faster in the summer than in the winter.

In my opinion ordinary water bacteria destroys sewage and has a very extensive effect upon the life of the typhoid bacillus.
7177 The details of the process are not known. We know it does. We know that they die out, and chemists and bacteriologists
7172 are working on the problem, trying to find out just how it happens.

In my opinion typhoid bacilli would not pass down to St. Louis
7173 under the ice.

I have had no practical experience with reference to the water
7175 supply of cities and investigation of those water supplies and in the formulation of the water systems of the city.

7176 I have made an analysis of private water supplies at Baltimore.

I said that in my opinion the Illinois River would be a safe
7184 water at Averyville if everything could be eliminated except the Chicago sewage, but I would not recommend it. I think

that I know enough chemistry and know enough eminent chemists to be able to appreciate the work of the chemists, and to be able to find out how good a chemist's works are. I have talked with Pro-
7185 fessors Long and Jordan in regard to the chemical situation at Averyville, and am giving their opinion. I got their opinion upon the subject before I had any idea of testifying in this
7187 case. I meet these men socially and talk over the general sanitary conditions and chemical conditions from time to time, because I am interested in these problems. I had no idea that I should testify in the case at all at that time.

I am familiar with the clinical and pathological phenomena in typhoid fever and malaria fever, with a great deal of knowledge regarding epidemics. I am here to give you any information that I can, and if you care to give me other data to use with those I have, I will be glad to give you any further opinion on that. I have collected a great deal of data upon the self-purification of streams. I have a great deal of general knowledge of bacteriology. I fear this is rather an immodest sort of a statement, but I must say it as you ask me to.

7197 I have gradually accumulated general conceptions about water supplies and sanitation in the course of the last fifteen years in chemical work. I have read some of the literature bearing upon the researches upon the conditions of the Illinois River. I have talked with others before I had any idea of testifying in this case with regard to the situation. I have formed judgments upon the situation. From all those together, and from my general knowledge of diseases, chemical and pathologic, mode and spread of typhoid, from the fact that I have received what I regard as reliable information concerning the existence of typhoid in cities below Chicago on the river, and that the sewage of some of these cities at least in which typhoid fever exists is poured into the river, on all of these taken together I have formed my opinion.

In regard to the conditions above Averyville, I have a map here that gives some information. It is a map of the Illinois River and its tributaries in the Journal of Experimental Medicine by Professor Jordan. I knew he would be sure to get a good map if he used one. It would take too long to give you all the data that I have collected. If I stated——

Q. I want to know just exactly what you did get.

MR. TODD: Give the details.

A. Well, as I understand it, the Illinois River receives a number of tributaries, including the Desplaines River, and the Fox and

the Kankakee and the Vermillion River and the Sangamon River and other streams of various size, and that these streams come into the river of course at different points. I understand that before the drainage canal was constructed that sewage was pumped from the Chicago River into the Illinois and Michigan canal, I think that is the name of it, and that that canal then emptied that sewage into the Illinois River, but that since the drainage canal was built the Chicago River is more directly connected without the aid of the pumping station. The sewage is poured into the canal at the upper part of the river. I should note that there are three or four locks on the river, that the stream is not a rapidly flowing stream, that in many parts of the river the rapidity of the flow is very low. I have understood that it is as low as one-half a mile in some places and that the conditions of flow of the stream are different at different times of the year.

I have been given to understand that not all of the sewage of the City of Chicago goes into the drainage canal at present; part of it still goes into the lake, but that an intercepting sewer is being built to lead more of the sewage into the drainage canal.

I understand that the current into the lake from the Chicago River before the drainage canal was built was a very slight one, and sometimes it almost tended to run the other way, and that the smell from the sewage became objectionable to the city, and that it was believed that the pouring of the Chicago River and its sewage into the lake was a detriment and menace to the city's health, and that the drainage canal was built in order to protect the city from this danger, and also from the nuisance.

I understand that this cost a great deal of money, many millions of dollars, more than thirty millions perhaps, and I have learned that on the banks of the river there are a number of towns which I have already named.

I learned that typhoid fever exists in at least some of those towns, and I have been told by men upon whose opinion I rely that the sewage from some of these towns in which typhoid fever exists is poured into the Illinois River, and that there is no adequate protection to either the river bank or the banks of tributaries of the river from contamination; that in fact the whole Illinois River is a drainage canal; that in one sense it might be regarded as a drainage canal, and a drainage canal that is polluted at a great many different places.

Then I have learned that the sewage deposited in through the drainage canal and in points below it had decreased with great rapidity in the number of bacteria which it contained, and that agrees with observation in other places under similar conditions.

I have learned further that the stream, so far as chemical and bacteriological analysis permit of a judgment, to be formed purifies itself gradually on the way down from Chicago to Peoria; that at Lockport and Joliet the contamination of the stream is still very great, probably still great from the City of Chicago, and at Morris there is still a great deal of contamination in the stream, but that from that point on there is a tolerably rapid, though gradual, diminution of the contamination of the stream as judged by bacteriological and chemical studies of the stream; that when Ottawa is reached there is a far less contamination than at Morris. At LaSalle the contamination is still less, and that at Henry it is very slight, whereas at Averyville the conditions are those of an ordinary river water that would ordinarily be regarded as a fairly good water, but that suddenly below Averyville, at Peoria, the river again becomes very badly polluted from the sewage of that city; indeed, while at Averyville, a few miles above Peoria, the stream is a tolerably pure water, even under present conditions; at Wesley, which is just below Peoria, the conditions are practically as bad as they are at Lockport, only thirty miles from Chicago; that this condition is also very bad at Pekin, and in all probability is exaggerated by the sewage poured into the river at Pekin, and below Wesley the river again tends to purify itself, and at Havana there is a remarkable diminution in the phenomena which chemists and bacteriologists regard as polluting phenomena, and at Beardstown still less, and at Kampsville still less, and when Grafton is reached the conditions are very much again like those at Averyville, so far as chemical and bacteriological studies are concerned, and the river compares quite favorably with ordinary river waters.

I have here the number of deaths from typhoid fever in some of the towns around the banks of this river. They have al-
7198 ready been put in evidence. I have introduced no hearsay, except that I regard as reliable.

7200 Q. Now, then, Doctor, what effect has proximity to the place of the source of pollution upon the sanitary conditions of water at a given point?

A. Well, given a certain rate of flow, and then the nearer
7202 the place to the source of pollution, the less the opportunity for self-purification.

In regard to the conditions of the water at Averyville and
7208 at Grafton I would state that I believe the water to be safe, but would not recommend its use without filtration.

7209 All information that I can gather or could gather would have an effect upon the formation of my opinion, and upon the in-

formation that I received I would be willing to state it as my opinion that the water at Grafton is probably safe, so far as the City of Chicago is concerned, so far as the sewage of the City of Chicago is concerned, but I would not recommend its use, be-
7212 cause I do not recommend any river water for use.

Considering all the conditions in the river, I would state it as my opinion that so far as the typhoid bacilli coming from Chicago are concerned, Grafton and St. Louis would not be menaced. I do not think that typhoid germs would come from Chicago to St. Louis in ten days under all the conditions of the river, and no con-
7213 ditions that will ever be realized will permit them to make the journey in ten days. If typhoid existed in Averyville there
7215 would be no evidence that it came from Chicago necessarily, not even if they use the water, on account of the contamination between Chicago and Averyville.

The evidence drawn from all the sources that I have mentioned make me have that opinion that typhoid germs would not live until they got to Averyville, and I said that I regarded the water in my opinion as reasonably safe, but I would not recommend it
7219 for use without filtration. By reasonably safe I mean as safe as most water supplies in this country.

The mortality in Philadelphia is about 33 per 100,000 and in St. Louis 34 per 100,000.

I have said that in my opinion the water at Averyville is reasonably safe after the sewage of Chicago is emptied into the drainage canal, and that in my opinion the Chicago sewage is not an
7221 element of danger.

I am of the opinion that the typhoid bacillus, while it lives, is undergoing changes all the time, and that where there is a destructive metabolism there must be also some catabolism. Where there
7222 is life there is change.

I teach sanitary science every day in the year, but not under that heading; under the heading of personal and individual hygiene. I said that in any sewage contaminated water it was my opinion that the majority of typhoid bacilli die out before from five to
7227 seven days on account of the exhaustion of the pabulum more quickly, either exhaustion of the food or the production of substances inimical to their life.

Q. Then your opinion could not be relied upon because you have not been furnished with proper information on all subjects bearing upon the controversy?

A. I should have to leave that to others to decide as to the value of my opinion.

The conditions in Lake Geneva are quite different from the conditions in the Illinois River. Geneva is a mountain lake, situated under the Dendu midi and at the outlet of the Roan Valley
7334 and the Roan River empties into it.

From my general knowledge of what occurs in septic operations I should say that a great deal had taken place in the drainage canal before reaching Lockport. I would call them septic, but perhaps others would not.

Q. Is it not a fact, doctor, that the attending physician is best able to judge of that matter, or, in other words, that the attending physician is best able to judge of the cause of the death or the nature of the disease?

7257 A. It is not a fact when large bodies of statistics are concerned that the statistics are always as reliable in regard to the cause of death as the opinion of men who are particularly skilled in internal medicine.

Q. Were you ever in actual practice, doctor?

A. I took the practice of my preceptor for a while in the country in Canada during one summer. I practiced medicine in the Toronto General Hospital for one year. I practiced medicine during the three months as head of the Children's Hospital at Mount Airy, Maryland. I practiced medicine in the Johns Hopkins Hospital the first year I was there, and I practiced medicine in the Phillippines and in Chicago. I occasionally see interesting and rare cases
7258 in consultation. My practice has, I think, been unusually interesting and helpful in developing me scientifically.

Q. The deduction I draw from this is that the doctors and physicians of the Southern cities are not as well educated as those in the Northern cities.

A. That is not a necessary deduction. The incidence of malaria is so much greater in Southern cities than in the North-
7260 ern cities that the opportunity for making a mistake is greater.

Q. What relation does malarial fever bear to water supply?

A. The relation of the water supply to the mosquito would be the only relation so far as the drinking water is concerned.
7251 There is absolutely no relation to malaria.

Q. Do you care to go on record as saying that a mosquito is the only thing that produces malaria?

A. I am willing to go on record as saying that there is no evidence that malaria is ever obtained by human beings except through the bite of a mosquito.

Q. And that is the only way it can be obtained, and if there were no mosquitos there would be no malaria?

A. In my opinion, there would not.

Q. How do you explain malaria in the Rocky Mountains in the west and in Blue Ridge?

A. If there were no mosquitoes there would be no malaria.

Q. Suppose that you were told that there was malaria there and no mosquitoes?

A. I would not believe it and I am sure that if I went there
7262 and examined the field there would be mosquitoes about there.

Q. Now, then, you don't know that there has been or has not been a falling off of malaria cases in the Mississippi Valley and in the City of St. Louis in the last three years, or since 1899, do you?

7263 A. I do know that malaria fever has caused no such death rate at any time as is reported by the column headed "Remittent, Intermittent, typho-malaria, congestive and simple continued fevers." I know that no disease should be classed under that column at present; it is a misnomer, and that means one of two things, typhoid or malaria. There are very few deaths from malaria, and one can see from his knowledge of malaria and typhoid that the deaths in that column were due really to typhoid; some of them to other things, like dysentery, acute tuberculosis, but scarcely anything would be termed really malaria which the terms remittent, intermit-
7264 tent, typho-malaria, congestive and simple continued fevers indicate.

Q. In other words, there is an increase in 1901 over conditions existing in 1900?

A. No. There is in typhoid alone, but not in the two groups together. The increase is not so great that what it might—it might occur in any year. For instance, if you examine the statistics further back you find in the years 1890, 1891, 1892, 1893 and 1894,
7265 more cases in the combined group.

Q. Then, doctor, attributing the typhoid in all instances to the pollution of the water supply, it simply means that the conditions in the water are not the same from year to year, although the source of the water supply is the same, is that true?

A. That is true.

Q. And the water at the intake is different one year from what it would be another year?

A. Assuming that all the deaths are due to water pollution?

Q. Yes.

A. It would indicate either that there were differences from year to year in the pollution of the water supply, or that for some

reason or another the people were more susceptible one year
7265 than another.

Q. But as an epidemiologist now, which would be considered as most likely to occur?

A. There is a possibility (if I may mention it), and that is, that there might be just the same degree of pollution, but the bacilli might be more virile in one year than in another, corresponding to the causes from which they have been derived. I don't think it would be easy to say where the difference is so slight as it is here, which factor was most concerned.

THEOBALD SMITH.

DIRECT EXAMINATION,

By Mr. Todd.

I am a professor in the Harvard Medical School and have served on the State Board of Health of Massachusetts; have been connected there since 1895, and prior to that time was bacteriologist and in charge of the investigation in the Department of Agriculture at Washington upon infectious diseases of animals. At the same time I was professor in bacteriology in the Columbia University medical department at Washington, District of Columbia. I am a graduate of Cornell University and Albany Medical College. After graduation I spent about six months in special work in Cornell and then went to Washington in the fall of 1883.

Q. Have you done any work on the bacteriology of water?

A. Yes. I began to be interested in that question in 1886, when I made observations upon the bacteriology of the Potomac River water. In 1891 I was engaged for a number of months on the sanitary survey of the Hudson River, between Schenectady and Albany, and last year I was engaged in looking over the bacteriology and the general sanitary status of the Charles River basin around Bos-
7288 ton, with reference to the building of a fresh water basin.
7289 I have given the question of typhoid fever consideration, because that is the main one involved in our climate, the bearing of drinking water upon typhoid and other intestinal infections.

The scope of the Massachusetts Board of Health is to take charge of the water supply of the whole state, and its business is to examine into the relative purity of water in the state, and also determine the best method of sewage disposal.

I have given considerable attention to the subject of bacteriology

as applied to water and pathogenic bacteria. I published about sixty or seventy papers on the subject of bacteriology, not exclusively in relation to drinking water, but in relation to diseases generally. I have studied practically all the pathogenic bacteria that are accessible, except the plague bacillus.

In studying the sanitary condition of the water I have taken it for granted that the most important indication would be the presence of fecal matter, because the typhoid bacillus, the bacillus dysentery, the bacillus of Asiatic cholera and the bacteria of all
7290 various diarrhoeal diseases are contained in relatively large numbers in the feces in the discharges during and perhaps some time after these diseases, and hence any test that would indicate the relative number of fecal bacteria would bring us as near to an exact determination of the sanitary conditions of a water as we could get. In the study of fecal bacteria there is one group of bacteria which is present not only in the human feces in large numbers, but also in the feces of domestic animals, and this group of bacilli is very closely related to and probably a progenitor of the typhoid bacillus, and any means of revealing the relative number of this particular bacillus, the bacillus coli communis, and its various varieties, I infer would enable us to judge as accurately as we can without being able to actually isolate the typhoid bacillus itself. It would enable us to judge as accurately as possible of the sanitary quality of the water with reference to fecal pollution. In view of the fact that our methods are still unsatisfactory in the isolation of the typhoid bacillus, the colon bacillus affords us the best indication of the possible presence of the typhoid bacillus. The colon bacillus is a parasite. The colon bacillus is a bacillus which is a parasite of the mucous membrane and the higher mammals. It is probably adapted to live on the mucous membrane more perfectly than any of the other bacteria that we are able to handle or study. It has so many characteristics in common with the typhoid that for years before certain tests were brought out they were confused, and
7291 this can easily be traced in the medical literature of the subject. In fact, when I was at Washington I sent to one of the most prominent medical schools of the country for a specimen of the typhoid bacillus, and I received a colon bacillus in return. The method I devised enabled me at once to tell the difference. For at least a good many years these two bacilli were confounded because they were so closely allied in their biological characters. But there are certain tests that enable us to distinguish them now without difficulty.

The typhoid bacillus is probably more perishable than the colon

bacillus under a variety of conditions. The colon bacillus is a more vigorous organism than the more highly parasitic typhoid. There are a number of tests that can be applied to determine their presence. By using agar plates, which enable us to determine whether certain acid forming bacteria are present, but this method is not the final method, and we have to examine such acid producing colonies subsequently to determine their nature, but the method which perhaps leads us more directly to the quantitative determinations of bacilli coli is the fermentation test. This test is one from which we are able to distinguish the colon from typhoid bacillus, and it is based on the fact that the typhoid bacillus does not produce gas in culture medis, such as beef broth, to which a certain quantity of dextrose has been added. The colon bacillus produces a certain amount of gas in this culture fluid in the fermentation tube. This fermentation test is perhaps the most satisfactory test we have for determining rapidly and promptly and within certain narrow limits of area the presence of colon bacillus in any organic fluid or in water.

It was in 1889 that I first came to form the idea of using fermentation tubes as a ready method of identifying certain pathogenic bacteria, and it occurred to me that the same method could be used to identify the colon bacillus, after I had found out that the colon bacillus acts like the pathogenic bacteria in the fermentation tube.

This test is used universally in this country for the recognition
7292 of this species. It is used as a chief test by the Massachu-
7293 setts State Board of Health in their filtration experiments.

I first published the method in the report of the State Board of Health for 1891 of New York. It is the best method we have at the present time and probably will not be superseded because there is no indication at present that we are any nearer to the direct determination of the typhoid bacillus than we were perhaps ten years ago.

Q. Is this method applicable to the problem of the self-purification of streams?

A. It seems to me it is, if by self-purification you mean the sanitary purification of the water for drinking purposes. If we take a small quantity of water, say 1 cubic centimeter, and add it in fractions of 1/10 cubic centimeter to a number of fermentation tubes, say ten, and place these in a thermostat, where only the colon bacillus and the relative pathogenic bacteria can multiply, and where the miscellaneous water bacteria are suppressed, then if after twenty-four or forty-eight hours in the fermentation tube we have a certain per cent. of gas, say in five out of ten tubes, we infer that in the cubic centimeter of water added there were five colon bacilli. The test is made

more accurate by reducing the amount of water that is placed in each tube. * * * If we had relatively pure water and should add a cubic centimeter of water to each of the number of tubes, and only a certain percentage of those tubes would show gas production, we should infer that in the ten cubic centimeters of water there would only be five or six colon bacilli, consequently there would not
7294 be a colon bacillus in each cubic centimeter of water.

The bacterial self-purification of streams consists in the reduction in the number of bacteria in the stream, which reduction is not due to an increase in the lower strata of the water, that is to say, not due simply to an imperfect or perfect sedimentation, but to the complete disappearance or destruction of the bacteria from the water under examination. I do not know of any general principles that determine how far a stream can flow before purification is noted, but I think that each stream has certain special local conditions that need to be looked into, which conditions depend on a variety of factors that vary from stream to stream, and what might be true of one stream might not necessarily be true of another. I think
7295 each stream under consideration must be investigated by itself.

I do not know of any investigation of a stream similar to that of the Illinois extending over such a distance. The colon then, in my opinion, is applicable to such a problem as that presented in the Illinois River. I know of one instance where a stream becomes practically free from colon bacilli, and I believe that has been worked out by Mr. Weston in the Mississippi River below New Orleans. The failure to find the colon bacillus would lead me to think that all other bacteria that are closely related to the colon bacillus, such as the typhoid and dysentery bacilli, and the various modifications of para-colon and para-typhoid, had also disappeared. The colon bacillus, as stated a few moments ago, is very closely related biologically to the typhoid bacillus, so closely that up to within a certain number of years the two were confused by many prominent bacteriologists. Its growth in bouillon is very much like that of the colon. The growth of the typhoid in gelatine is very much like that of the colon bacillus. It is only when we come to certain chemical tests that the divergence begins. The typhoid bacillus does not produce indol, which means that it does not split up certain nitrogenous substances in the
7296 way that the colon bacillus does. The typhoid bacillus does not ferment certain sugars that the colon does.

There are thus very few differences between the typhoid and the colon bacillus and we are justified in inferring that the different

changes the colon undergoes are undergone in nature outside of the human body also by the typhoid. Whatever degeneration or changes the colon undergoes are also undergone by the typhoid, but perhaps more rapidly under certain conditions, because the typhoid is more parasitic. It has probably less certain defensive properties and less adapted to live outside of the human body, and the reduced power to live will also favor the increased destruction of the typhoid bacillus in nature, a destruction which we generally assume is much more rapid than that of the more vigorous intestinal colon bacillus. The typhoid bacillus does not increase and multiply in nature; it will grow rapidly in milk, but before the milk becomes very acid.

I have examined Professor Jordan's data relative to the abund-
7297 ance of the colon in the waters of the drainage canal and up the Illinois River, for the year 1901, made at the laboratories at Peoria, Grafton and St. Louis, and introduced in evidence in this case. I made a particularly careful examination of his tables.

I should assume that the colon bacilli had very largely disappeared in their passage down the Illinois River, and the colon content of the Illinois River at Grafton is therefore less than that of the Missouri and Mississippi Rivers, or at least about the same. It would seem that the condition of the water at the mouth of the Illinois River was certainly not inferior, if not superior, to that of the Mississippi River and the Missouri River at these points, as I read the tes-
timony in these tables. The Missouri River is on the whole
7298 more polluted than the Illinois. According to these figures there is not very much difference, but the benefit of the doubt rests with the Illinois River without any question. * * * I should say that the Illinois River was superior in its sanitary qualities to either of the other rivers, the Mississippi or Missouri. It seems to me that a careful study of the colon results obtained by Professor Jordan with some of the tributaries are slightly better than the Illinois at that point and some are worse. According to these tables there is an enormous destruction of colon bacilli down to Averyville in the Illinois, and basing myself on this I should say that a similar, if not greater, destruction of typhoid bacilli had taken place down to that point. It seems to me that if virulent typhoid bacilli should pass from Chicago to the mouth of the Illinois River, that it would be according to conditions and laws that we know nothing about, but that basing ourselves upon the close relationship of the colon to the typhoid bacillus and to this entire group of disease germs, we are at present justified in saying that the virulent typhoid bacilli would be very largely destroyed at that point. It would seem to me that the

disappearance of the colon bacilli indicates that excluding a large amount of sewage which enters below Chicago, the typhoid bacillus would probably be entirely eliminated during that long course from Chicago to the mouth of the Illinois River, of three hundred and fifty-odd miles. I know of no bacteriological evidence that in my opinion affords a more suitable indication than the one in question, to wit: the colon determinations. There is no direct bacteriological method by which it could be demonstrated that the typhoid bacillus actually does pass from Chicago to St. Louis, and if it were
7300 done it would be largely a matter of accident. If a typhoid bacillus should be discovered in the water supply at St. Louis it would be utterly impossible to identify the source of such typhoid bacillus. The presumption would be that the typhoid bacillus would come from the nearest sewage discharging point. The question as to whether a typhoid bacillus can pass from Chicago to St. Louis is one of probability only, and it seems to me wholly so, and my opinion is based upon the index of the disappearance of the bacillus which is so closely related to it that for many years it has been mis-
7301 taken for it.

That is, the colon bacillus. It seems to me that, considering the enormous destruction of the colon bacillus from Chicago
7301 down to Averyville, the very great influx of sewage at Peoria that the presumptive evidence is very strong that the typhoid bacilli from Chicago would not reach St. Louis, because it is highly probable that the colon bacilli at the mouth of the Illinois River are probably those that have been introduced further down the stream, say at Peoria and other sewage discharge places. The effect of polluted water upon the life of the typhoid germ is a very difficult question to answer categorically. It would depend upon the temperature there and depend upon the amount of pollution. It is possible further, that if the pollution is very great that these pathogenic bacilli under favorable temperature might begin to multiply for a very short period of time, and in the course of this multiplication would become destroyed, because they thereby would render themselves vulnerable to destruction. That is to say, it is possible that the sewage might afford enough stimulus for these pathogenic bacteria to induce them to multiply and then to become destroyed. Of course, if that is so, sewage would be extremely dangerous, just at that time. But if we pass beyond that period, it would become less dangerous because of the increased destruction of these pathogenic bacteria.

The history of typhoid epidemics in the past has shown that
7302 the typhoid bacillus can be carried by relatively pure water.
Whether the polluted water is a hindrance to the destruction or favors it, is a question which I think has been only recently approached experimentally by Professor Jordan, and I do not feel quite competent to make any statement as to that. If I did it would be merely in the form of an opinion.

Q. If it were true that a relation obtained between typhoid fever in Chicago and typhoid fever in St. Louis, would you not expect this relationship to be shown in an indication between typhoid rates in Chicago and in St. Louis?

A. I should think that the two curves of typhoid would be very much alike, and the St. Louis curve would be slightly retarded in time. Viewing the charts of Professor Mason, I am unable to see any direct connection between the typhoid curve of Chicago and that of St. Louis from these diagrams. The upper curve in the St. Louis chart is one which seems to correspond with the usual summer and fall increase in typhoid which is manifest throughout the civilized world, and I fail to see any direct relationship between the two.

Q. Is there a rise in the typhoid in the fall in other cities in this country aside from Chicago and St. Louis?

A. I think it is generally conceded that typhoid fever in our hospitals grows in August, September and October each year.
7303 That is the time when cases are looked for.

I have examined the typhoid fever statistics introduced in evidence in this case. From colon determinations of the Mississippi River at the chain of rocks, I should hardly consider the river water a satisfactory water for public use without previous preparation or previous filtration.

Knowing the typhoid conditions in the City of St. Louis, and assuming that the same were due to the water supply, I should first look to the points nearer by all means, and if those could be eliminated, then I think I should look to the City of Chicago. I think it would be highly important to locate the nearest sources first because of the vulnerability of the typhoid bacillus in water. The further the area of infection the less the danger of typhoid bacilli reaching the water supply. A few bacilli discharged into a stream near by would be much more dangerous than a large number discharged at a much greater distance.

I am acquainted with the experiments made by Professors Jordan, Zeit and Russel. The results of Professors Jordan, Zeit and Russel have introduced a new factor into the problem, and they have

defined for us perhaps for the first time the viability of the typhoid bacillus in polluted water. Before that time, of course, the results were not very definite, unless we take into account the viability of the colon bacillus, but now it seems that the typhoid bacillus is fairly rapidly destroyed in polluted water, more rapidly than we have believed, and that rapidity of destruction would indicate what I suggested a moment ago, that possibly the typhoid bacillus is stimulated enough to multiply in sewage polluted water to be promptly destroyed. Whereas in water which contains very little organic matter its life is preserved a longer time because of the condition of latency
7305 and absence of that stimulation to multiply, which I assume is very destructive to bacteria in general. If these experiments are correct, and I feel quite prepared to take the risk of accepting all of those experiments of Professor Jordan and the other gentlemen—if they are correct—then I think it would be physically impossible for a typhoid bacillus to reach St. Louis, starting at Chicago.

I have made a special study of the germ test for twenty years and have made a special study of typhoid and malaria. The diagnosis of typhoid is made free by the state at the state laboratory, and any physician can send in specimens of blood prepared in certain ways for diagnosis, and we advise all physicians to use these methods of diagnosis in order to increase the accuracy of their diagnostic work. Malaria can as a rule be easily recognized by the examination of the blood with the microscope. Malaria is not a fatal disease north of the tropics. There were only two cases which I recall during my eight years of observation in Massachusetts. There may have been others, but these two I recall, because I was investigating cases at the time. It is very rare that typhoid fever and malarial fever co-exist, and these cases are so rare as generally to go on record in medical publications. These terms, and especially the term remittent fever, figured quite extensively in medical publications twenty years ago, but since that time it has almost wholly disappeared because of
7306 the more accurate means of diagnosis.

The classification of intermittent, remittent, typho-malaria, congestive and simple continued fevers, is at least a very indefinite form of classification, because that would assume that under the terms remittent, simple continued and typho-malaria, we would have either one or the other disease, either typhoid or malaria, or a mixture of the two, which rarely occurs. The classification as you have named it would indicate that the best means of diagnosis were not resorted to in determining the nature of these diseases.

7307 CROSS-EXAMINATION,

By Mr. Corum.

The difficulty of finding the colon bacillus in 300 cc. of water practically means the same thing as purification from a sanitary point of view. That number of colon bacilli means an exceedingly small percentage of colon bacilli as compared with other pure spring and surface water, and whether the water has been diluted, or 7310 whether the river has been purified, the result is practically the same.

The evidence upon which I am basing my statement, and I think it is perfectly reliable, shows that the colon bacilli largely disappear at Averyville, or before they have reached this second source of contamination—the group of towns at Peoria—consequently, it would be inferred that the colon bacilli which are at St. Louis are largely recruited from the places further down, and that the colon bacilli which have almost disappeared at Averyville would have completely 7312 disappeared at the mouth of the Illinois River.

VICTOR C. VAUGHAN.

DIRECT EXAMINATION,

By Mr. Todd.

I am a physician and a teacher in the University of Michigan at Ann Arbor. Graduated in 1875. I have studied with Robert Koch in the University of Berlin, and have been there two or three times. The longest time I was there was about three months in 7313 1888. I have made a special study of the germ diseases and have been a member of the Michigan State Board of Health, serving my third term now; have been called upon frequently to examine into the epidemics in the state, and I served on the government commission, and am still serving the United States Government Commission for the study of typhoid fever. My enlistment in the army was June 9, 1898, and the special commission appointed to study typhoid fever was in 1898, in August.

After my return from Santiago there was a commission appointed to investigate the causes and spread of typhoid fever in the camps of the United States. This commission consisted of the late Major Walter Reed, the late Major Shakespeare and myself. We went to Camps Alger, Fernandino, Jacksonville, Huntsville, Chickamauga, Knoxville, and Camp Meade, Pennsylvania. I have seen sev-

eral thousand cases of typhoid, four or five thousand probably. As a member of the commission I have been engaged practically ever since that time in arriving at the statistics and studying the spread of typhoid fever, and I have been called upon frequently to investigate
outbreaks of typhoid fever in different parts of the country,
7314 in Michigan, and other states as well. Our commission had
charge of all the diagnoses that were made of the army camps after the appointment of the commission. I have had experience both in the laboratory and at the bed-side.

Remittent, intermittent, typho-malaria, congestive and simple continued fevers are not distinct types of disease and so recognized by bacteriologists and clinicians. When these terms appear in vital statistics they almost invariably—there are some exceptions, but almost invariably—they mean typhoid fever.

Assuming the number of deaths reported from typhoid fever in the City of St. Louis as they appear in the public health reports, I dare say there were more deaths from typhoid fever than are reported. Assuming the number of deaths from remittent, etc., fevers, the number of deaths reported under typhoid fever alone, do not
properly represent, in my opinion, the number of deaths actu-
7316 ally occurring in the City of St. Louis for the period in
question.

My experience shows me that malaria is not a common disease in Missouri or in that section of the country. The disease itself is rare and death from the disease is exceedingly rare, so rare that practically it does not occur. You may ask me what I base that statement on. Missouri sent six regiments to the war in 1898. I have studied the records of all these regiments, and although in some of them many cases were diagnosed by the surgeon as malaria, more careful examination was instituted by our Board, showing these were not malaria cases, but they were cases of typhoid fever. One of these regiments remained, if I remember correctly—I can tell positively by looking at the records—in Jeffersonville Barracks—practically a part of St. Louis, until July, 1898. While malaria was frequently reported by the medical officers in charge of this regiment, more careful examination showed that they were cases of typhoid fever. For instance, the Sixth Missouri developed 286 cases of typhoid fever and had nineteen deaths from typhoid fever. The Sixth Missouri was stationed at Jeffersonville Barracks until early in August, I have not the exact date; it then went to Jacksonville, Florida, and there our Board inspected the Sixth Missouri and studied the cases clinically

and bacteriologically. They were cases of typhoid fever and
7317 not cases of malaria. Of eighty-three cases of so-called malaria from the Fifth Maryland that were sent to the hospital in Baltimore, eighty cases proved to be typhoid fever. I think that is just about right; it was about that per cent.

Q. To what do you attribute the failure of these statistics assumed in the foregoing hypothetical question to properly disclose the number of deaths from typhoid fever occurring in the City of St. Louis?

A. For the reasons just given, that malaria is certainly a very rare disease in Missouri, and death from malaria is much rarer in this section of the United States. I would say that I do not know very much about the local conditions existing in the City of St. Louis, but in the State of Missouri I know somewhat. I was born and reared in Missouri. I know something about it. I go back there nearly every year. I know something about the conditions existing in Missouri.

Why doctors employ these terms there are many reasons. In the first place, typhoid fever in its earliest stages is often a remittent disease; that is, it is a disease where fever exists for a few hours and then there is no fever. In its earliest stages it is a remittent disease; that is one reason why it is done. The second reason why it is done is that doctors really think they are dealing with malaria when they have typhoid fever, and I have no doubt the third reason that actuates doctors in using these terms is that they are less likely to frighten the patient and the friends of the patient. It does not seem quite as terrible a thing to have malaria fever as to have typhoid fever, and the fourth reason is that the means of accurately distinguishing between malaria and typhoid fever have been discovered only within recent years, and often now are not always in the hands of practicing physicians.

These I think, in sum and substance, are the reasons why doc-
7318 tors so frequently use these terms when actually they have typhoid fever to deal with.

I am sure there is no city in the United States where there are so many deaths from malarial fever as reported in St. Louis. Of course, there may be cities where the deaths reported are equal to those in St. Louis, but there are no cities where there are that many malarial deaths. I think 100 per cent. of the intermittent group should be classed as typhoid fever. Now, of course, there may be a few of them that were not typhoid fever, they may have been something else.

Q. What proportion as malarial fever?

A. None. There are practically no deaths from malarial fever in this country unless it is in New Orleans or some other extremely southern city. Of course, there may be two or three in a year in a large city. In Albany five cases were reported in the last
7319 year from malaria, but it is very doubtful if they were real malaria.

It is generally recognized by bacteriologists and clinicians that classifying these fevers in this manner is an improper classification as affording a true indication of the mortality from typhoid fever and malaria.

Assuming the deaths from typhoid fever under table "A" and the intermittent fevers under table "B" by the month from 1895 to 1903, as given in the table, I think the total deaths there, as reported from all of these causes, more accurately gives the number of deaths from typhoid fever. Without knowing anything about the local conditions in St. Louis, simply as a student of epidemiology, looking at the distribution of these diseases according to months, I should say that the probabilities are that typhoid fever in St. Louis, with the possible exception of the year 1892, was due to local causes rather than to any infection of the general water supply. When
7321 there is an infection of the general water supply, as a rule, the outbreak of typhoid fever is explosive in character; that is, there are a great number of cases which occur within a short time. They are not distributed along so evenly through the months. That is the rule. There may be exceptions. I do not know about the local conditions, but when there are positive infections (certain infections of the water supply) the outbreak of typhoid fever is of an explosive character, as happened at Grand Forks, N. D., some years ago; Duluth, Minn.; at Butler, Pa., recently; Plymouth, Pa., some years ago; Ithaca, N. Y., recently, and as now occurring at Watertown, N. Y. That is the general rule of epidemics due to the infection of the water supply.

As already stated a few moments ago, these figures as given here showing the distribution of typhoid fever render it highly probable that the local conditions, such as infected or polluted wells, indicated the distribution of typhoid fever by contact were the causes of the start of typhoid fever in St. Louis rather than the infection of the general water supply. I should answer your question then specifically by saying that polluted wells, if they were specifically polluted with typhoid fever, the use of the water from such wells would un-
7322 doubtedly cause typhoid fever.

If you take the typhoid statistics included in the table just

assumed for the years 1890 to 1899, inclusive, you have total deaths of 3708 for ten years. That would give an average death rate of 370. If you take the four years since 1899, it would give you 1,261 deaths, or an average of 315 deaths, so there would be, if you include all the years from 1892 to 1903, inclusive, then the average would be
greater before 1900 than since 1900. If you cut out the years
7323 1892 and 1893, it would be smaller.

The letter sent out by the Department of Health of St. Louis probably does manifest itself in those statistics. I should assume that the object in sending out such a letter was to get a more perfect report of deaths from typhoid fever, and I should judge from the figures you see here of the deaths from malaria that such object was accomplished. This fact is manifest by an increase in the number of deaths reported from typhoid fever, while there is a loss, I believe, in the typho-malaria column. While in 1901 there were only 80 cases, the smallest number in any one year from and including 1900, in fact, the three years—1901, 1902 and 1903—the number of deaths reported as being due to malaria is less than in any preceding
7324 year.

The two tables taken separately do not correctly show the
7324 death rate from typhoid.

My opinion is based upon the fact, which is well known to most physicians, and certainly I have special reasons for knowing it, that malaria is not a frequent disease in this country, and is certainly a very rare cause of death. These two columns of figures should be combined in order to arrive at the typhoid fever mortality in the City of St. Louis.

I have made some studies of the comparison between typhoid fever in St. Louis and typhoid fever in other cities. I have here the number of cases reported and the number of deaths in each year from 1876 to 1902, inclusive, for New York, Minneapolis, Philadelphia, Richmond, Buffalo, Albany, Cleveland, and it is rather interesting to note that the typhoid rate in Buffalo has increased quite markedly since 1899, the year that the drainage canal was opened. In 1896 there were 274 cases in Buffalo reported, with 68 deaths; in 1897, 201 cases, with 63 deaths; 1898, 280 cases reported, with 98 deaths; 1899, 212 cases reported, with 88 deaths; 1900, 322 cases reported, with 90 deaths; 1901, 405 cases, with 98 deaths, and in 1902, 385 cases, with 125 deaths. Of course, in New York there has been a big increase in typhoid fever. I imagine, however, that is due to the enlarging of the city rather than to any other cause. The cases there jump from 1,950 in 1899 to 2,658 in 1900, and in 1902 get up to

3,871. In Minneapolis there has been an increase, if we exclude the year 1897, when there was an epidemic of typhoid fever in
7325 Minneapolis.

I have an idea, and I think most epidemiologists have the idea, that typhoid fever has been more widely disseminated over the country, and there are more cases and more deaths from typhoid fever. I do not mean that the per cent. of deaths has increased, but the number of cases has increased, and consequently the number of deaths has increased, and I daresay that this is in part due to the distribution of typhoid fever from the camps in 1898; that is probable. St. Louis does not occupy a different position in regard to this increase; there are other cities which show some increase. Of course, I might have picked out cities that showed marked increase, but these are cities which I have already looked up in making my government report, and I simply cited them as I had them.

7326 Assuming the statistics in the table entitled "Typhoid fever death rate, St. Louis death rate per hundred thousand," there certainly has been some increase, unless we go back to the epidemic years, of course, and take in 1890 and 1891. Typhoid fever, if we take that alone, then there has been an increase. If we leave out 1892 and 1893, with the exception that in the year 1898 there was a drop, I believe. There was also a drop in 1896 compared with 1895, and a drop in 1895 compared with 1894. The increase, as I have observed, it is not such as would be characterized as epidemic. An epidemic of typhoid fever, and especially a water epidemic of typhoid fever, is where the increase in typhoid fever amounts up to 100 per
7328 cent. or more, and even 200, 300 or 400 per cent. The character and nature of the increase that I have observed on the whole is a gradual increase, such as you might expect would be due to local conditions, especially if wells were getting more and more filthy and were not condemned.

I have seen the charts offered in evidence by Professor Mason. These charts would indicate that there is no casual relation between typhoid fever in Chicago and typhoid fever in St. Louis, because if there was the charts would have the same general curve, charting the typhoid fever in St. Louis, one month later than the typhoid fever in Chicago. Such relation is not shown by these charts.

If from a consideration of the typhoid conditions as they exist in St. Louis, as evidenced by the typhoid statistics assumed, both from the typho-malaria and typhoid death columns, I was called upon to attribute a cause, I should look for the cause certainly in St. Louis in the local conditions. It is generally assumed that typhoid fever is

carried altogether by means of drinking water. This is wholly an erroneous assumption. We have some charts here which illustrate that if you care to have me exhibit them.

Here is a chart of a regiment which happens to be the 15th Minnesota, as they were in camp upon the fair grounds at St. Paul and Fort Snelling. These men were drinking the same water, and
7328 while some companies remained practically free from typhoid fever, other companies were largely infected. Typhoid fever, if it once starts, often spreads by contact from person to person, infection of houses, clothing, bedding, etc. Especially is this likely to be the case in crowded parts of cities, and it is certainly true, or was true, among our troops. Typhoid fever was spread by what we call tent or comrade infection.

Typhoid fever in St. Louis since 1900 certainly does not differ from some other cities. Of course, there are certain cities in which there has been an increase, and in some of these a much more marked increase than in St. Louis.

I think that there is no evidence, so far as I can see, from these figures, that the drainage canal has had anything to do with the typhoid fever in St. Louis, for the following reasons:

In the first place, as I have already stated, the distribution of typhoid fever in St. Louis, as shown in these tables, is indicative of local contamination and spreading by contact rather than of any general water infection. In the second place, there are certain cities in the list I have given here where the increase in typhoid fever has been more marked than in St. Louis, and in these cases, notably that of Buffalo, the drainage of Chicago has been turned away from Buffalo rather than to it. I think that there has been a gradual increase of typhoid fever throughout the country for the last few years, and the increase in St. Louis has been gradual. It has been slow and I do not think from the evidence that there has been any great contamination of the water supply of St. Louis. There have been
7329 no explosive outbreaks of typhoid fever.

Q. Do you know of any instance where typhoid fever has been spread by contact?

A. I have already shown the table illustrating the spread of typhoid fever in the 15th Minnesota, where it was spread by contact. There are still more direct illustrations offered.

In 1898 the Seventh Army Corps was stationed at Jacksonville, Florida, consisting of 30,000 men. The number of deaths from typhoid fever was 421. This army corps was at Jacksonville only during the summer. The population of Jacksonville at that time was

in round numbers 30,000. The soldiers and the people at Jacksonville drank the same water from the same artesian well. There were during the whole year of 1898 nine deaths from typhoid fever, if we take those reported as only typhoid. If we take all those that were reported as due to typhoid fever, remittent, intermittent, typho-malaria fevers, the total number of deaths among the people of Jacksonville was twenty-one. In other words, there were 400 more deaths from typhoid fever among the 30,000 soldiers there, and they were there for only about three months, than there was for the whole year among the 30,000 people of Jacksonville, and all drinking the same water.

This illustrates that typhoid fever is often spread by other means than by drinking water.

There was one division encamped at Knoxville, and we spent some time investigating the conditions at Knoxville, but we could find no case of typhoid fever in Knoxville among the citizens;
7330 at the same time there were many hundreds of cases among the soldiers, and they were drinking the same water.

EBEN J. WARD.

DIRECT EXAMINATION,

By Mr. Todd.

I am a civil engineer since 1880 and took my degree at Sheffield Scientific School at Yale in 1880. Have made a survey of the Illinois River for the purpose of ascertaining the number of acres that were inundated on the bottoms of the Illinois River in 1890 be-
7332 tween Lake Joliet and the mouth of the Illinois River, and in 1892 between Lake Joliet and the La Grange dam. The flood of 1890 was what we would call an upper river flood. From the eastern line of Grundy County to La Grange Dam my estimate in 1892 of the number of acres overflowed was 200,000.

Q. How many acres would you estimate the amount of land subject to overflow along the Illinois Valley from Lake Joliet to the mouth of the river?

A. In the neighborhood of 400,000 acres.

CROSS-EXAMINATION.

7333 There has been one or two levee districts in that.

RE-DIRECT EXAMINATION.

By Mr. Todd.

Q. As a practical proposition, do you believe the Illinois River could be leveed for the purpose of creating any value to the land lying behind such levees that the cost of the levees would not exceed the cost of the land?

A. I would not consider it a good commercial proposition to
7336 levee the Illinois River for tillable purposes except here and there, just as they have selected and placed locations.

LEONARD P. KENNICUTT.

DIRECT EXAMINATION,

By Mr. Todd.

I am director of the chemical department of the Worcester Polytechnic Institute, located at Worcester, Mass. Graduated at the Massachusetts Institute of Technology; studied in the University of Heidelberg for two years; then studied two years in the University of Bonn, Germany, in the laboratory of Professor Kekule; then studied four months at Johns Hopkins Uniersity; then at Harvard University, where I obtained the degree of doctor of science. Was instructor in chemistry in Harvard University for three years, and from there was appointed assistant and subsequently professor
7336 of chemistry, and then director of the department of chemistry in Worcester Polytechnic Institute, which office I now hold. Have been consulting chemist of the Worcester Board of Health since 1885. Was consulting chemist to the Connecticut Sewage Commission appointed by the legislature. Am vice-president of the American Association for the Advancement of Science; a member of the American, English and German Chemical Societies, and member of the American Bacteriological Society.

Have made a special study of sanitary problems since 1882; also of the analyses of water both chemical and bacteriological, and am continually employed in making such determinations. Have had experience in the interpretation of both chemical and bateriological results. Have had experience in passing on the water supply
7337 of numerous cities. Have made a special study of the typhoid bacillus, as related to water supplies; also the coli bacillus.
7338 Am acquainted with the physical conditions of the waterway between Chicago and St. Louis and made the trip by tug, rail and boat in September from Chicago to St. Louis.

I have made special investigation on the question of sewage disposal problem, beginning in 1882, when I was asked to give my advice to the City of Worcester regarding the disposal of the city sewage. I have conducted experiments of my own, lasting through periods of over two years, on the question of purification of sewage by septic tank, having a tank in continuous operation, holding over 1,500 gallons. I have visited all the sewage purification plants in Massachusetts and have visited most of those in England. Since 1896 I have visted England every other year, studying what was being done in England regarding the method of treatment of sew-

7339 age.

7340 Description of a septic tank.

7341-2 Operation of a septic tank covered, and uncovered.

I have studied the sanitary canal from the standpoint of a septic tank and have prepared tables based upon Professor Jordan's and Professor Long's analyses showing septic operation in the drainage canal.

7343 Tables of analyses showing the changes which took place dur-

7344-46 ing the passage of the sewage of Chicago through the sanitary canal from April to June, in 1900, and June to September, 1900, and July to October, in 1900.

7347 Table "D," mean of Professors Jordan, Long and Palmer's analyses compiled from tables 1, 2 and 3, showing the changes, parts removed and the per cent. of purification that took place during the passage of the sewage of Chicago through the sani-

7348 tary canal.

Table "E," showing the action of a septic tank on removal of substances contained in sewage in various cities.

From the analyses that I have made showing the character of the water at Lockport and the character of the water entering the canal at Kedzie avenue, these results indicate very clearly that the septic action has taken place during the passage of water containing sewage through this canal, as shown by the increase in free ammonia, the decrease in albuminoid ammonia, soluble albuminoid ammonia; also in the decrease in oxygen consumed, soluble and suspended; that the results agree in their general characteristics with results that have been obtained by the examination of crude sewage and the effluent from the septic tank in the various places that I have given in table "E." The changes are exactly the same in character, the difference being only in amount.

Q. What effect does this septic action, as you have described it, have upon the sewage as it passes through the drainage canal?

A. It has a purifying effect; it also renders the substances which still remain in the sewage more evenly acted upon when the sewage enters the river, and it purifies the sewage by removing a part of the solid matter that was in the sewage by throwing it down to the bottom of the canal and by the removal of the solid matter by changing it into gas.

7349

The effect of septic action which I described as taking place in the drainage canal upon the bacterial life of the sewage, both pathogenic and non-pathogenic, I will say that my opinion is that it diminishes the number of bacilli coli and the more delicate pathogenic germs, and that the total number of bacteria is diminished by 10 or 15 per cent.

7350

Sanitary conclusions to be drawn from the presence of the different chemical elements when found by determinations in water. Chlorine. Albuminoid ammonia. Free ammonia. Nitrites. Nitrates. Total organic nitrogen. Oxygen consumed.*

7351

7353

I have studied the chemical data prepared by Professors Long, Jordan, Palmer, Burrill and Zeit.

From the tables of Professor Long, given in the Illinois State Board of Health, 1901, which are the results of his examination of the waters of the various stations from Chicago to Grafton, on the Illinois, both for 1899 and 1900, I draw the following conclusion:

Table No. 2, Bridgeport. Results are such as can be obtained from diluted sewage.

Table No. 3, Lockport canal. Results obtained at this point are very similar to the results at Bridgeport during the same period.

Table No. 5, Joliet. The distance of Joliet from Lockport is only four miles, and the results show that but little change has taken place in the sewage in its flow from Lockport to Joliet.

Table No. 7, Morris. The water of the Kankakee River is a much purer water than that of the Desplaines River at its point of junction, and so the water of the Desplaines is purified to a certain degree by dilution.

7355

Table No. 8, Ottawa. There has been a very decided change in the purity of the water between Morris and Ottawa, a distance of about twenty-four miles.

Table No. 10, La Salle. These samples were taken about 600 feet above the mouth of the Big Vermillion, and although there has been some dilution, as shown by the reduction in chlorine, and the

*Note definitions. These definitions are worthy of serious consideration

very decided decrease in free and albuminoid ammonia, with corresponding increase in nitrogen as nitrates, and the decided decrease in oxygen consumed, shows that during the stretch of river between Ottawa and La Salle the processes of purification have been very active.

Table No. 12, Henry. The slight increase in chlorine would
7356 indicate a slight addition of sewage to the river, probably from La Salle and Peru. Total population, 20,000. There has, however, been only slight changes between.

Table 13, Peoria Narrows. The chlorine shows that there has been more or less dilution between Henry and the Narrows, but the great change has been in the removal of free ammonia and nitrogen as nitrites. This shows that the principal change between Henry and the Narrows has been the last process in the changing of the organic matters of sewage into mineral matters.

Table 14, Wesley City. The increase in all the different constituents shows that a large amount of organic matter has been added to the river between Peoria Narrows and Wesley City, a distance of only about six miles.

Table 15, Havana. We see here, as at Peoria Narrows, the final changes of organic matter into mineral matter taking place.

Table 26, Grafton. The water at Grafton, as shown by the analysis, has been so purified between Havana and Grafton that it now closely resembles the water at Peoria Narrows.

Table 21, Grafton on the Mississippi. The amount of organic nitrogenous and carbonaceous matter in the two rivers is about the same as shown by the albuminoid ammonia and oxygen consumed.

I have also prepared tables from the results of Professor Long's analysis at the various stations from Chicago to Grafton from June to October, 1900.

Table 41, Chicago city water. These analyses would indicate
7359 that the water was not quite as pure in 1899 as 1900, but are results that would be obtained in a potable water.

Table 43, Western avenue bridge, drainage canal. If this is compared with the analysis of the water of the Illinois and Michigan canal in 1899 at Bridgeport, it is seen that it is a very much more diluted sewage or sewage mixed with a much larger amount of water.

Table 44, Lockport canal. These analyses were taken in connection with table 43. As I have already pointed out, it shows that the diluted sewage has undergone very decided changes in its passage through the canal.

Table 45, Joliet, Desplaines River. This shows that the water

is not as pure as it has been up there, and when compared with the analyses made in 1899, shows that it contains very much less organic matter than it did at that time.

Table 46, Morris. The water is very much purer than in 1899.

Table 47, Ottawa. There has been even more marked purification of the water in its run of twenty-four miles in 1900 than in 1899, as shown by the reductions of free albuminoid ammonia
7359 and oxygen consumed and by increase of nitrites and nitrates. There has been little if any dilution, as shown by the chlorine. The water is much purer than in 1899.

Table 49, La Salle. The purification which was noted at Ottawa has continued. The chlorine shows the effect of slight dilution. River much purer than in 1899.

Table 51, Henry. The results similar to those obtained in 1899 and slight increase in chlorine indicate the addition of the sewage of La Salle and Peru. Slight changes as regard organic matter. River purer than in 1899.

Table 52, Peoria Narrows. The change, as was the case in 1899, is the decrease in free ammonia, albuminoid ammonia and nitrogen as nitrites. Water much purer than in 1899.

Table 53, Wesley City. The analyses show the addition of the sewage of Peoria.

Table 54, Pekin. As in 1899, a great amount of purification
7360 seems to have taken place between Wesley City and Pekin, a distance of nine miles. River much purer than in 1899.

Table 55, Havana. We have here in the twenty-four miles similar results to 1899, a very slight increase in free ammonia and in nitrates, and a slight decrease in albuminoid ammonia.

Table 58, Grafton. The water between Havana and Grafton has been so purified that the nitrates and chlorine are the only indications of the pollution of the river at Peoria.

Table 59, Grafton on the Mississippi. The great difference in the Mississippi at Grafton from the Illinois at Grafton in 1900, as in 1899, was in the amount of chlorine, 2 against 10.6, and in the suspended matter. The Mississippi, as shown by the albuminoid ammonia and oxygen consumed, contained in 1900 more organic matter than the Illinois in 1900, and figures for oxygen consumed show a greater amount of organic matter both in solution and suspension.

I have prepared tables of chemical and bacterial analyses of Professors Jordan, Palmer, Burrill and Zeit, as they appear in Streams Examinations, which have been introduced in evidence in

this case, and the tables of Professor Long as they appear in the Board of Health reports.

7361 The general method was to obtain the mean of the averages of the analyses made by these various named persons during given periods of examination, which tables have already been introduced in evidence, and during times which were comparable with each other.

7363-68 Tables, Illinois River, 1899, Joliet, Morris, Ottawa, La Salle, Henry, Averyville, Wesley City, Pekin, Havana, Beardstown, Kampsville, Grafton, based on the mean of Professors Jordan and Palmer, results, May to December.

Chart, mean results Illinois River, chemical table, Jordan and
7370 Palmer, months of May to December, inclusive, of 1899.

The rapid decrease in the amount of ammonia, free and albuminoid, and the oxygen consumed from Joliet to Morris, and at the same time the increase in nitrogen as nitrites and nitrates, shows the amount of purification that has taken place between these places.

* * * As we proceed down the river from Ottawa to La
7371 Salle, the curve shows continued purification. Below La Salle the purification continued down to Averyville. At Averyville the chart shows, as was shown by Professor Long's table of results, the final change of the organic to the inorganic matter. From Averyville to Wesley City we notice the effect of the contamination at Peoria. Between Wesley City and Pekin the purification again begins, and this purification continues all the way down to Grafton. If we again compare results of Professor Long with the mean of Professors Jordan and Palmer, we find a close agreement as regards the condition of the water at Grafton.

I have prepared tables based upon the chemical analyses of Professors Jordan and Palmer for the months from January to June, inclusive, for 1900. The tables that I have prepared are numbered from 53 to 64, inclusive.

Table of Illinois River at Joliet, Morris, Ottawa, La Salle,
7374-79 Henry, Averyville, Wesley City, Pekin, Havana, Beardstown, Kampsville, Grafton, based on the mean of Jordan and Palmer's results, January to June, 1900.

Chart based upon the table of mean results, Illinois River, chemical table, Jordan and Palmer, January to June, inclusive, of 1900.

The chart just introduced demonstrates at Joliet that the
7381 amount of free ammonia, albuminoid ammonia and oxygen consumed is not one-half as great as in 1899, showing much less pollution of the river in 1900 than in 1899. There is, as in 1900,

a rapid fall in the curves representing the amount of free ammonia and albuminoid ammonia and oxygen consumed in the stretch of river between Joliet and Ottawa, with corresponding rise in nitrogen as nitrites and nitrates, showing that the active zone of decomposition is, as in 1899, in the neighborhood of Ottawa. There is a slight increase in the oxygen consumed curve between Ottawa and La Salle. There is then a steady elimination of organic matter from the river down to Averyville, as shown by the gradual decrease of the curves for free ammonia, albuminoid ammonia, nitrogen as nitrites and oxygen consumed, with an increase of nitrogen as nitrates. It is also to be noted that the increase in the albuminoid ammonia curve continued down to Pekin, while in 1899 the decrease began between Wesley City and Pekin. From Pekin to Havana there is a gradual decrease in the organic nitrogenous matter.

7382 The purification of the river from Havana to Grafton is indicated on the curves by the gradually increasing amount of nitrogen as nitrates, the decrease in free ammonia and albuminoid ammonia not being so evident on account of spring thaws and freshets.

Considering the two charts together, the curves on the chart representing the river from June to January, in 1899, closely resemble the curves given on the chart representing the river from January to June, 1900, showing that the general character of the purification that took place is the same for the two years, the small difference being chiefly due to the effect of dilution and to seasonable variations that took place in the river. Both charts show the purification that took place between Joliet and Ottawa in both years, and that the zone of the most active decomposition of organic matter has not been shoved or been pushed farther down the river

7383 by the increasing volume of the river due to the opening of the sanitary canal. The purification is then shown to con-

7384 tinue in both years as the river flows to Averyville. The river in both years, as shown by the curve, purifies itself again between Wesley City and Grafton, as it did between Joliet and Averyville.

I have prepared a chart based upon the bacterial tables of Professors Burrill and Jordan for the months of May to December, inclusive, for 1899.

Chart based on mean results, Illinois River bacterial table, Burrill and Jordan, May to December, 1899.

A study of the chart just introduced in evidence in connection with the chart for the chemical data of the same period, shows a striking agreement between the chemical and bacterial data. The

mer and autumn months of 1899 than in the spring months
7390 of 1900. The soil bacteria washing into a stream during the late winter and early spring months always increases largely the number of bacteria in a river during that period.

I have prepared tables based upon Professors Jordan and Palmer's analyses for the months of June to December, 1899, showing comparisons in the sanitary character of the tributaries of the Illinois River, numbered from 65 to 72, inclusive.

7391 Table 65, Desplaines River at Lockport, 1899.
Table 66, Kankakee River at Wilmington, 1899.

7392 Table 67, Fox River at Ottawa.
Table 68, Big Vermillion River at La Salle.

7393 Table 69, Sangamon River at Chandlerville, 1899.
Table 70, Mississippi River at Grafton, 1899.

7394 Table 71, Missouri River at Alton, 1899.
Table 72, Illinois River at Grafton, 1899.

7395 I have prepared a chart based upon the tables just introduced with the caption "Mean results comparisons of the sanitary character of the tributaries of the Illinois River at their mouths with the Illinois River at Grafton, Professors Jordan and Palmer,
7396 months of June to December, inclusive, 1899."

The chart requires very little explanation, as it is seen by the eye that the waters of the Desplaines, the Kankakee, the Fox, at their mouths, the Mississippi at Grafton, the Missouri at West Alton, contained in 1899 as much or more albuminoid ammonia and oxygen consumed than the Illinois at Grafton.

As regards the purity of these streams as shown by chemical charts and data and by these curves, I should say that the waters of these various rivers were about in the same condition in 1899 as the Illinois River at its mouth, with the exception of the Mis-
7397 souri River at West Alton, which contained more organic matter.

I have prepared a bacterial chart from the same tables based upon the results of Professors Burrill and Jordan, for the months of June to December, inclusive, 1899. The chart with the caption "Mean results, comparisons of the number of bacteria in the tributaries of the Illinois River at their mouths with the Illinois River at Grafton, Burrill and Jordan, months of June to December, inclusive, 1899."

7399 The Desplaines River at its mouth contains about 6,000 more bacteria per cc. than the Illinois River at Grafton, while the Missouri at West Alton contains about 7,000 more bacteria per cc. than

bacteria which number over one million per cc. at Joliet decrease very rapidly to La Salle. In this distance of about sixty-two miles the number has fallen from one million to 17,412 per cc. This shows, as did the chemical results, that the zone of greatest purification is near Ottawa. From Henry the number falls steadily until Averyville is reached, the number there being 4,756 per cc. Then, on account of the pollution entering the river at Peoria, the number rises immediately to 995,503. This sudden rise in the number of bacteria shows how quickly sewage pollution can be detected by bacterial examination. From this point the number of bacteria rapidly falls and at Kampsville there are only 7,457 per cc., showing the great amount of purification that has taken place between Wesley City and Kampsville. Between Kampsville and Grafton there has been, as was the case between La Salle and Henry, a very slight increase in the number of bacteria, 2,005 per cc. This increase is not at all significant, as a slight increase at this point after the rapid decrease be-

7387 tween Wesley City and Kampsville is absolutely without significance as regards the problem of stream purification.

I have prepared a chart based upon the bacterial tables from

7388 Professors Burrill and Jordan's tables for the months of January to June, inclusive, 1900.

Chart: Mean Results, Illinois River Bacterial Table, Burrill and Jordan, January to June, 1900.

This chart shows the amount of bacteria at Joliet to be about 900,000 per cc., falling to 110,000 at Ottawa, showing that the greatest amount of purification took place exactly as it did in 1899, in the neighborhood of Ottawa. Between Ottawa and La Salle there is a slight increase in bacteria corresponding to the slight increase in the oxygen consumed, as shown in the chart representing the chemical data for this same period. From Ottawa to Averyville the number of bacteria rapidly decreases until at Averyville one cc. contained about 45,000 bacteria. At Wesley City there is an increase in bacteria amounting to 60,000, and which continues to increase until Pekin is reached. The rapid purification in the spring months does not begin until after the river passes Pekin. From Pekin to Havana the curve falls rapidly, showing that great purification has taken place. At Kampsville and Grafton there was in 1899 a slight increase in the number of bacteria, but the number at Grafton is less than at Averyville, showing the removal of the polluting material entering the river at Peoria. As was to be expected, the number of bacteria in the lower stretches of the river is greater during the sum-

does the Illinois at Grafton, the Kankakee, the Big Vermillion and the Sangamon Rivers, from one to two thousand less bacteria per cc. than the Illinois River at Grafton, while the Fox and the Mississippi at Grafton about 4,000 fewer bacteria to the cc. than the Illinois at Grafton.

As to the condition as shown by the number of bacteria, the Desplaines and the Missouri would seem to be in a less satisfactory condition, and the Fox, and the Mississippi River at Grafton in a slightly better condition than the Illinois at Grafton from May to December, 1899. There appears to be not any great difference in this repect as regards the condition of the Kankakee and the Sangamon Rivers at their mouths and the Illinois River at Grafton.

7400 I have prepared tables based upon the mean results of Professors Jordan and Palmer of the tributaries of the Illinois River at their mouths with the Illinois River at Grafton for the months of January to June, inclusive, 1900, and numbered

7401-5 73 to 80, inclusive.

TABLES.

I have prepared a chart based upon the tables just introduced with the caption "Mean results, comparison of the sanitary character of the tributaries of the Illinois River at their mouths with the Illinois River at Grafton, Professors Jordan and Palmer, months of January to June, inclusive, 1900."

7406 This chart shows that the Mississippi at Grafton and the Missouri at West Alton contained from January to June, 1900, more undecomposed organic matter than the Illinois at Grafton; that the Kankakee and the Fox contained about the same amount, and the Big Vermillion and the Sangamon less undecomposed organic matter. The nitrogen as nitrites is much less than in the Illinois River at Grafton in 1900 than in 1899, while the amount in the Mississippi, the Missouri, the Desplaines and the Big Vermillion is about the same in the two different parts of the year.

7407 I have prepared charts comparing the number of bacteria in the tributaries of the Illinois River at their mouths with the Illinois River at Grafton, based upon the bacterial results of Professors Burrill and Jordan, for the months of January to June, inclusive, 1900.

7409 CHART.

This chart shows that the Missouri River contained more bacteria during these months than the Illinois at Grafton. The other

rivers all contained a less amount per cc. than the Illinois at Grafton. The difference in this respect between the Mississippi at Grafton and the Illinois at Grafton, however, is not great. The bacterial contents of the river is three to four times greater than during the period in June to January, 1899. This was to be expected, as this chart shows the number of bacteria during the late winter and spring months, during which period a great number of saprophytes or soil bacteria are brought into the river by thaws and spring freshets, and on this account the total number of bacteria does not give as good an idea as to the sanitary character of the water of the rivers as the chart of the autumn months.

I have prepared tables based upon the mean chemical results
7410 of Professors Jordan, Long and Palmer, for the months of May, June, July and August, for the years 1899 and 1900,
7411 and the tables are numbered from 1 to 24, inclusive.

Tables 1 to 24, inclusive, of the Illinois River, Joliet, Morris,
7412 Ottawa, La Salle, Henry, Averyville, Wesley City, Pekin, Havana, Grafton, Beardstown, Kampsville, for 1899 and 1900.

7423 I have prepared two charts based upon tables, from 1 to 24, under the caption "Mean results, Illinois River, chemical table,
7425 Jordan, Long, Palmer, months of May, June, July and August of years noted.

7426 The resemblances of the various curves for 1899 and 1900 show that the general processes of purification took place in the same after the opening of the canal as before it was opened. It is also to be noted that with the exception of the curves, representing suspended solid matter, suspended oxygen consumed and nitrogen as nitrates, that the curves for 1900 are below the curves for 1899, showing that in 1900 a given volume of the river contained less organic impurity than in 1899. * * * The curves representing the free and albuminoid ammonia show a very large amount of organic matter in both years at Joliet, a sharp decrease to Ottawa, and then a gradual decrease to Averyville. The curves, especially the curve representing albuminoid ammonia, rise slightly between Averyville and Pekin, showing the effect of the population at Peoria, and then both gradually falling until Grafton is reached, where the minimum amount of both free and albuminoid ammonia is shown by the curve to be present. The nitrogen curves, especially the nitrogen as nitrites, show that the zone of greatest decomposition in the upper stretches of the river in both years is in the neighborhood of Ottawa, and that the added volume due to the opening of the sanitary canal

has not pushed this zone of decomposition further down the
7429 river. * * * The curves also show that the given volume of the river water contained less organic nitrogenous matter in 1900 than in 1899.

I prepared a chart based upon the bacterial results of Professors Zeit, Burrill and Jordan, as contained in the tables 1 to 24, inclusive, already introduced in evidence, the caption of the table being "Mean results, Illinois River, bacterial tables, Professors Zeit, Burrill and Jordan, months of May, June, July and August, of the years noted."

Both curves show a great number of bacteria per cc. at Joliet. They then show a great decrease between Joliet and La Salle, a distance of sixty-five miles. The curves for 1899 show that between La Salle and Henry the number of bacteria increased rapidly, owing, probably, to sewage of La Salle and Peru, and decreased almost as rapidly between Henry and Averyville. The curve for 1900 shows also a slight increase from bacteria between La Salle and Henry and also a further increase between Henry and Averyville, due, probably, to some local cause. Between Averyville and Wesley City the two show an increase of bacteria in both years, greater, however, between Wesley City and Pekin in 1899 than in 1900. In both years the curves show a very great decrease between Wesley City and Havana, a distance of forty miles, and the decrease continued, however, not so rapidly, between Havana and Beardstown. The curve for 1900 shows this decrease continues to Kampsville, while the curve shows a rise between Beardstown and Kampsville. In both years they show an increased number between Kampsville and Grafton. The curves show only three places in the river where the bacteria was greater in 1900 than in 1899, namely, Averyville, Havana and Beardstown. The
number of bacteria at Grafton is shown to be about 6,000 less
7431 per cc. in 1900 than in 1899.

I have prepared tables based on analytical data of Professors Jordan and Palmer on the tributaries of the Illinois River at their mouths with the Illinois River at Grafton for the months of May and June, numbered 25 to 40.

7432-40 Tables 25 to 40.

I have prepared a chart based on the tables with the caption "Mean results, comparison of the sanitary character of the tributaries of the Illinois River at their mouths with the Illinois River at Grafton, Jordan and Palmer, months of May and June, 1899 and
7441 1900."

CHART.

The chart just introduced shows, in the first place, that the Illinois River at Grafton contained much less organic impurity in May and June, 1900, than it did in the corresponding months of 1899. With the exception of the Big Vermillion, all the tributaries to the Illinois and the Mississippi at Grafton contained more nitrogenous and easily oxidizable matter during May and June, 1899, than did the Illinois at Grafton during the same months. It is also seen to be the same for 1900. Excepting the Big Vermillion, all the tributaries to the Illinois and also the Mississippi at Grafton and the Missouri at West Alton, contained more nitrogenous organic and easily oxidizable matter than did the Illinois at Grafton during the same period.

The chart also shows that during May and June, 1899, the Illinois contained more nitrogen and free ammonia than did its tributaries during the same months, but during May and June, 1900, it is seen that it contained less than the Desplaines, the Kankakee, the Fox and the Big Vermillion, and practically the same amount as the Missouri.

7442 I have prepared a chart based upon the bacterial results of Professors Burrill and Jordan for the months of May and June, 1899 and 1900, upon the results in the tables which have just been introduced. The chart with the caption "Mean results, comparison of the sanitary character of the tributaries of the Illinois River at their mouths with the Illinois River at Grafton, Burrill and Jordan, bacterial tables, months of May and June, 1899 and 1900."

7444 This chart shows that the Illinois River at Grafton during the months of May and June, 1899, contained over 10,000 more bacteria per cc. than during the same months of 1900. It also shows that the Illinois River at Grafton during the months of May and June, 1899, contained more bacteria per cc. than did any of its tributaries, and more than the Mississippi at its mouth during the same months. During May and June of 1900 the Illinois River at Grafton contained, excluding the Fox River, not only less bacteria per cc. than any of its tributaries, less than the Mississippi at Grafton and the Missouri at West Alton, during the same months of 1900, but also contained a less number of bacteria than did any of its tributaries, with one exception, the Big Vermillion, during the corresponding months of 1899. The Missouri at West Alton is shown by the chart to contain over 40,000 more bacteria per cc. during May

and June, 1900, than the Illinois at Grafton, the Illinois at Grafton containing only 8,740 per cc. The Missouri at West Alton during the months of May and June, 1900, was, from bacterial representation, much more polluted than the Illinois at Grafton.

Q. Professor, in preparing these charts and tables, why did you take the mean?

A. The reason I took the mean was because it is my opinion that in taking a mean of the analytical data obtained by the various observers at the various stations on the Illinois River, more accurate information would be obtained of the changes that took place in the river, than by studying the data of only one person. Probably I did this because it is a method commonly employed in all scientific investigations, as, for instance, what are now considered as the figures representing the correct amount of hydrogen and oxygen in water were obtained not from the results of a single observer, but by combining the data of many different experiments made by many
7446 different observers.

STEPS OF PURIFICATION OF CHICAGO SEWAGE.

The sewage of Chicago as it enters from the sewers into the drainage canal undoubtedly contains a small amount of oxygen, and the first action that takes place is undoubtedly anaerobic action, in which part of such substances like urea are decomposed, ammonia being given off. The action in the sanitary canal is an anaerobic action of similar nature to that which takes place in the septic tank. By this action about 20 per cent. of the organic matter, as measured both by the albuminoid ammonia and by the loss in oxygen consumed, is removed from the sewage. Also a certain amount of sus-
7446 pended matter is removed, and a certain amount of suspended matter has been rendered soluble, and a certain amount has been converted into gases and into simpler products. By this action the sewage is not only purified but changed, so that further purification will take place more easily.

The next stage in the purification is the aerobic stage. Undoubtedly, in the upper stretches of the river near Joliet, I think aerobic and anaerobic action takes place. Further down, as at Ottawa, we have probably an aerobic or nitrifying action. At about this point both in 1899 and 1900 is the zone of greatest decomposition. From this point the action, in my opinion, is entirely an anaerobic or nitrifying action, continued purification going on until we come to Averyville. * * * The purification continues and between Pekin and Havana the action that takes place is an aerobic or a nitrifying action.

The aerobic purification then goes on until at Grafton all the original organic matter which was in the sewage at Pekin has been decomposed and changed.

EFFECT OF EMPTYING CHICAGO SEWAGE INTO THE CANAL.

The effect of emptying the sewage of Chicago into the drainage canal, into the Desplaines River at Joliet, and then into the Illinois River, is to increase the amount of organic matter in the upper stretches of the river. The effect, however, of adding this organic matter to the upper stretches of the river is not noticed at Averyville except in the increased nitrogen contents of the river and the high chlorine, and the same can be said at Grafton at the mouth of the Illinois River. At that point the effect of the addition of the sewage to the Illinois River is seen in the high chlorine and the nitrogen as nitrates. This nitrogen content of the river is probably different from the nitrogen content of the river at or above Ottawa. This nitrogen has been changed over and over again from the original character in which it occurred at Joliet. How this change takes place I have tried to show in my description of the nitrogen cycle. (Page 7354, Record.) * * *

I think the chart representing the Illinois River, May, June, July and August, 1899 and 1900, which was produced in evidence yesterday, shows clearly the condition of the Illinois River in comparable months in 1899 and 1900. This chart compared the state of the river in corresponding periods in 1899 and 1900, and showed that the purification took place almost exactly in the same way during these two periods, the zone of greatest decomposition being in both years in the neighborhood of Ottawa. * * * All the data as given by the two charts showed that the purification of the river took place in the two years in exactly the same way, and also that the river at all points was purer than during May, June, July and August in 1900 than in 1899.

My opinion is, as has been shown by my answers to the pre-
7448 vious questions, that I believe that the sewage of Chicago is entirely decomposed before Grafton is reached, and that the only effect which we perceive in the river at Grafton is the nitrogen content and in high chlorine. These elements are not [illegible] rous to public health in the slightest degree. They have, so far as I know, no effect upon the human system.

Taking into consideration all the data that I have presented and

all the data that I have studied regarding the Illinois River, and assuming that you mean by deleterious matters any matters that were in the sewers of Chicago that were deleterious to human health, and by infectious matter that you mean typhoid bacilli, I do not believe that they reach down the Illinois River as far as Grafton.

My reasons in full for this answer are that in my opinion all of the deleterious substances which may have been considered to have been contained in the Chicago sewage, meaning by deleterious substances any bacterial life, have been entirely decomposed and
7449 rendered absolutely harmless long before the river reaches Grafton, and that the infected matter, meaning by that typhoid bacilli, which enters into the drainage canal from the sewers of Chicago, would not survive the passage from Chicago to Grafton.

It is my opinion that the water of the Mississippi River west of the center of the main channel of said river at the mouth of the Illinois River and down to the intake tower of the St. Louis waterworks at the chain of rocks is not less valuable for drinking purposes and not more liable to carry water-borne diseases now than it was before the sewage from the sanitary district of Chicago was run into the drainage canal. I do not believe that any increased speed of the current of the Illinois River that would be caused by the addition of the water of the drainage canal would have any effect in increasing or diminishing the typhoid or liability to typhoid and other water-borne diseases on the part of the inhabitants of the State of Missouri using the water of the Mississippi River for drinking purposes below the mouth of the Illinois River, and my opinion is based
7450 upon the character of the Illinois River.

My opinion is that the typhoid fever germs could not live for weeks or months or even years in gradually diminishing numbers in the Illinois River, for all the experiments with which I am familiar show that the typhoid germ will live a less time in a polluted water than in a pure water. From the experiments that have been made, I do not believe that the typhoid bacilli would live until they entered the slack water at Peoria. And assuming it should be deposited for a period of a month, I do not believe they would live for that period in such a deposit, and in this connection I would like to call attention to the experiments of the Massachusetts State Board of Health, and also cite in this connection an article on the investigation
7451 of the River Severn in the Shrewsbury District of England.
7452 From all the data that I possess and from all the knowledge that I have acquired regarding the life of the typhoid bacilli, I do not think it is possible that the waters leaving Lake Peoria would

contain at times more infectious and dangerous pollution than is at present in the polluted sewage entering Bear Trap dam at the foot of the drainage canal.

I am very clearly of the opinion that the water of Lake Peoria cannot at any time contain as much infectious and dangerous material as the waters at Bear Trap dam, and I know absolutely of no data that would warrant any such ssumption.

Knowing the character of the Illinois River and bearing in mind the amount of sedimentation and amount of dilution and the amount of purification that occurs between Chicago and Grafton, and especially bearing in mind the time limit, I do believe that the time interval would render the Mississippi River water at all times free from liability of producing water-borne diseases from pathogenic bacteria entering the Illinois River by way of the drainage canal.

From all the knowledge that I possess as a sanitary expert I do not believe that the waters of the Illinois River at Grafton is infected from the sewage of Chicago, meaning by infection typhoid bacilli which come into the Illinois River from the Chicago sewage, and this being my opinion, I do not consider that the water from the Illinois River mixed with the water of the Mississippi at Grafton and subsequently mixed with the water of the Missouri River at its mouth, thus commingling with the waters of the Mississippi and Missouri, is a menace to the inhabitants living upon the Mississippi River using the Mississippi River for drinking purposes at points on the Missouri shore.

7454 It being my opinion that typhoid fever bacilli from Chicago entering the Illinois River do not survive the journey from Chicago to Grafton, assuming that there were no typhoid fever pollution in the waters upon the watershed of the Mississippi River or its tributaries above the intake of the St. Louis waterworks except that which came from Chicago, my opinion is, for the reason stated before, that typhoid fever germs from said district are not liable to find their way into the water supply of the City of St. Louis, through the intake tower at the chain of rocks. I can find no evidence that shows that the typhoid bacilli does or can pass from Chicago out into the Illinois River, thence to the chain of rocks to the intake tower at St. Louis.

From all the data that I have studied and from all the knowledge that I have been able to obtain regarding the Illinois River, I find not the slightest evidence that the Illinois River, containing the mixed sewage and canal water from the Chicago drainage district since the opening of the drainage canal renders the water of the Mississippi River below the mouth of the Illinois River less safe and

wholesome than it was before the opening of the canal for drinking purposes on the part of the inhabitants of Missouri.

From various experiments that have been made it has been shown that the vitality of the typhoid bacilli is greater in pure water than in water polluted by sewage, and basing my opinion on these facts, it is my opinion that the sewage from Chicago does not favor the longevity or growth of germs from Peoria or anywhere else emptying their sewage into the Illinois River.

It is absolutely necessary to employ both chemistry and bacteriology, and it is impossible to form a correct judgment as to the quality and potability of a water without the aid of both of these sciences. In passing judgment on the sanitary character of a river it is almost absolutely necessary to have a knowledge of the source of pollution and a knowledge of the watershed. Without a knowledge of the nature of the watershed it is almost
7457 impossible to form a correct idea of chemistry and bacteriology alone of changes taking place in the river.

From all the tables that I have studied and the various analyses that have been made upon the waters of the Illinois River, all indicate that the zone of the greatest decomposition in both 1899 and 1900 before and after the sanitary canal was opened in the upper stretches of the river was in the neighborhood of Ottawa. In the lower stretches of river there is in both years another zone of decomposition somewhere between Pekin and Havana. In my opinion the zone of greatest decomposition is shown to be by nitrogen as nitrites. The zone of purification is shown by the change of the nitrites into nitrates, that being the last change which organic matters undergo, it being transformed into mineral substances. The zone of purification immediately follows the zone of greatest decomposition.

My opinion is that if it was possible for the typhoid bacillus to remain in the sediment of a polluted stream for a period in excess of sixty days, the viability of the typhoid bacillus would be so greatly diminished that when taken into the human system in all human
7458 probability it would not be able to cause typhoid fever.

From my knowledge of the Illinois River, flowing as it does at high water over a very large amount of territory, and the fact that the river is studded with lakes nearly all the way from Upper Peoria Lake to its mouth, I do not believe that even at the different stages the water of the Illinois River the sewage from the City of Chicago passing through the drainage canal into the Illinois at different seasons of the year would be a danger or a menace to the inhabitants of

Missouri and the citizens of the City of St. Louis using the water of the Mississippi River at the intake tower at the chain of rocks.

From chemical and bacterial analyses introduced in evidence by Professors Long, Palmer, Burrill and Jordan, together with my study of the tables and charts that I have prepared and introduced as evidence, it is my opinion that the Mississippi and the Illinois practically contain about the same amount of impurity, while the Missouri River contains a larger amount of impurity than either of the other two rivers mentioned.

The effect of the waters of the Illinois River emptying into the Mississippi under the conditions stated would be one of purification upon the combined waters of the Mississippi and the Missouri
7459 Rivers, and would render those waters less harmful. A steady mixing does not create any added danger.

It is my opinion as a sanitary expert, and with a knowledge of the conditions that obtain in and along the Illinois River, and from the evidence that has been submitted in this case, that such infected matter or pathogenic germs which come into the drainage canal from Chicago do not reach as far down the Illinois River as the City of Grafton. If they would not reach as far down the Illinois River as the City of Grafton, it is impossible that any of these substances in a dangerous state would reach the intake tower of the St. Louis waterworks at the chain of rocks. For the reasons already stated, I do not consider the sewage of Chicago a menace and a danger to the inhabitants of the State of Missouri, or to the citizens of the City of St. Louis, taking their water supply from the Mississippi
7460 River.

From a study of the analytical data which has been submitted in evidence in this case, it is my opinion that all these analytical data show that this organic matter of the sewage from Chicago has been decomposed before it reaches Grafton, consequently none of the organic matter from the sewage of Chicago finds its way into the intake tower of the St. Louis waterworks at the chain of rocks. In my opinion, the water supply of St. Louis is not contaminated or polluted or injured by the sewage of Chicago. It is a well known fact that the larger amount of surface over which the water spreads, the greater will be the amount of deposition, consequently, the increased water at flood times, causing a larger area of land to be overflowed along the Illinois River, would tend to cause a greater deposition of the suspended matter coming from the sewage of Chicago and entering the Illinois River through its canal.

From the examinations that have been made and the finding of

the coli bacilli in the majority of one cc. samples, I do not believe that the Mississippi River at the chain of rocks was, prior to 1900, a safe and potable drinking water, fitted for domestic and drinking purposes in its raw state; neither was the Missouri River water
7462 nor the Illinois for the same reasons stated.

It is my opinion all the examinations that I have studied, as well as my own tables and charts show, that the watters of the Illinois River at Grafton are in a purer state since the opening of the drainage canal. They are certainly not less sanitary than the waters of the Mississippi River and they are in a better sanitary condition, as shown by the bacterial and chemical analyses, than the waters of the Missouri River. The only effect, in my opinion, that the sewage discharged through the drainage canal has upon the Missouri or the Mississippi River waters at the chain of rocks, is in the increase in the amount of chlorine, and also in the quantity of nitrogen contents, neither of which elements, so far as known, has any effect upon the human system. The sewage of Chicago, as sewage, in my opinion, never reaches the Mississippi at the chain of rocks at the
7463 intake tower.

I do not consider that either the waters of the Mississippi or the Missouri are a safe and suitable water for drinking by the citizens of Missouri.

It is my opinion that all of the organic matter contained in the sewage of Chicago has been entirely decomposed and changed before the river reaches Grafton, and it is also my opinion, based upon all the knowledge that I possess, that the infected matter, meaning by that the typhoid bacilli, have not been able to survive the journey from Chicago to Grafton.

Taking into consideration all the analytical data I have examined and studied, including the chemical and bacterial analyses made upon the waters of the Illinois River and its tributaries, my own tables and charts, and at the same time taking into consideration certain towns discharging into the Illinois River and its tributaries, and taking also into consideration the rural and urban population upon this water shed, my opinion is that there is no evidence that the flowing of the sewage of the City of Chicago from the drainage canal into the Desplaines River has any effect upon the inhabitants using the water of the Mississippi River for drinking and domestic purposes.

NOTE—This witness was heard from 2 P. M. March 16th, to
7464 March 17th, and no cross-examination was made.

7465 WILLIAM S. THAYER.

DIRECT EXAMINATION,

By Mr. Todd.

Am a physician. Graduated at Harvard University in 1899; spent a year as house physician at the Massachusetts General Hospital; after that I spent a year abroad in studying in Germany and in Vienna, and in the fall of 1890 came to Baltimore as assistant resident physician in the Johns Hopkins Hospital. In 1891 I was appointed resident physician, and in the fall of 1895 I was made associate in medicine at the John Hopkins University, and 1896 or 1897 associate professor of medicine, which I have been since then. I lived in the Hospital as resident physician from 1891 to 1898. I studied in Paris three months during the fall of 1893. I am one of the physicians in chief of the Johns Hopkins Hospital Dispensary, associate in medicine at the Johns Hopkins University, associate professor of medicine in the Johns Hopkins University, and visiting physician to the new Protestant Infirmary. Have given special attention to in-

7466 ternal medicine and special study to so-called germ diseases. I have been studying typhoid fever and malaria steadily since the beginning of my practice, and I have made special investigations in regard to the parasites of malarial fever. I have had considerable experience in the diagnosis of this disease, both at the bed-side and in the laboratory, since the summer of 1888.

7466 Typhoid fever and its clinical diagnosis.

There is no disease in which experience is more important than typhoid fever.

Experience in connection with malarial fever given in de-

7469 tail.

7470 Malaria fever and its clinical diagnosis.

The malarial fevers are recognizable and diagnosticable by the examination of the blood under the microscope, and the demonstration of the parasites, and need never be confounded with typhoid fever. They are also recognizable fully by the fact that they are curable by quinine. The only patients with malaria fever properly treated who ever die are certain cases of extremely pernicious aestivo-autumnal malarial cases, which die within forty-eight hours, perhaps, of the beginning of the treatment. No case of continued malaria which could be confounded with typhoid fever need ever be fatal; they always clear up under treatment with quinine, and no case of typhoid fever which lasts more than four or five days after treatment

with quinine is malaria. That is a statement which in my experience can be positively made. The only known way by which malaria can be carried is by the bite of a mosquito. The malarial parasites of all three varieties possess two cycles, one of which they pass in the stomach wall and in the salivary gland, in certain types of mosquito, members of the genus anopheles. The other cycle they undergo in the human being.

So far as known and so far as believed by all who have ever devoted themselves to the subject of malarial parasites, they do not exist outside of the human being or the mosquito. If a mosquito of the genus anopheles at a fitting time of the year, when the temperature is warm enough, bites a patient whose blood contains certain forms of malarial parasites, at the end of seven or eight days that mosquito will be capable of transferring infection by bite to another human being.

After careful investigation during the last six years since this discovery has been made, there has not been revealed a single instance where malaria has originated except in the presence of
7471 this type of mosquito.

Q. Have you ever found a parasite of malaria in a mosquito?

A. Yes, I have. I have fed mosquitoes on patients whose blood contained malarial parasites, and demonstrated intermediate stages in the mosquito's stomach.

The experiment of Patrick Manson in London with a mosquito imported from Rome.

Malaria is not as prevalent in the center of a city as in the outskirts, as the opportunity for the mosquito to live is better in
7473 the suburbs of a town than in the center of the city. Mosquitoes will live for two months.

7474-75 Description of intermittent, remittent, typho-malaria, congestive and simply continued fevers.

Q. Are remittent, intermittent, typho-malaria, congestive and simply continued fevers distinct types of disease and so recognized by doctors and clinicians?

A. No; they are not. They are simply terms describing symptoms. I should regard these terms when they appear in vital statistics as representing in the vast majority of cases typhoid fever.

Assuming that the number of deaths in the annual reports of St. Louis from typhoid fevers and the number of deaths under the head of remittent, etc., fevers in the same reports, I should say unquestionably that the number of deaths reported as occurring from typhoid fever alone in the City of St. Louis do not properly represent,

in my opinion, the total number of deaths actually occurring in that city. My reasons are as follows:

I should say in the first place that a considerable personal experience with cases in which these very diagnoses have been made have shown me that in almost every instance they represent typhoid fever. I should say, furthermore, that in the fourteen years' experience in the Johns Hopkins Hospital I have never made, and I know that there does not stand on the books, a single diagnosis such as appears in the list which you gave of the remittent, typho-malaria, etc., fevers, and further, from the fact that the deaths from malarial fever itself in this city and in this neighborhood, which is a malarious neighborhood, occur in extremely small proportions as compared with those of

typhoid fever, I should say that in view of all these facts, as
7476 well as in view of the fact that in other cities in which these

diagnoses used to be made, they have now been abandoned entirely; these cases being all classed as typhoid fever. In view of all these facts I should feel perfectly certain in my own mind that the great majority of these cases represent typhoid fever. Let me say that in my own experience in the Johns Hopkins Hospital, since the opening of the hospital, I have not been here since the opening of the hospital, I came here in the year after it was opened, but I have the statistics of that year, there have been 130 deaths from typhoid fever, just four deaths from malaria, and no deaths ascribed to any other causes. Then, again, the observations of men of confidence who looked into the conditions during the Spanish-American war show that the diagnosis of typho-malaria or simple continued fevers, or remittent fever, as well as a vast majority of the diagnoses of malarial fever, were incorrect, that the condition was purely and simply typhoid fever.

Let me add just one more word in regard to the question of malarial fever in particular, and the diagnosis of remittent fever, and all that sort of thing. When a man hands in a diagnosis of remittent

fever, it is perfectly safe to say that in the great majority of
7477 instances he believes its nature to be malarial. Now those

fevers are—anybody who knows anything about practice in this country knows that a case of remittent fever so diagnosticated is never allowed to go through its course without treatment with quinine, and anybody who has had sufficient experience with malaria and sufficient knowledge of its nature knows that if those cases were malaria not one of them would die. They would all recover.

The reasons why doctors employ the terms remittent, intermit-

tent, typho-malaria, congestive and simple continued fever.*

7480 A comparison of the malarial deaths of St. Louis with other cities of the country.*

*This answer is important.

I should say that a perfectly safe estimate would be to classify at least seven-eighths of the deaths under typho-malaria as typhoid fever. If one desired to get the relevant frequency of typhoid fever from year to year, I think the adding together of the two

7482 columns would give as correct an idea as any other method.

The other one-eighth I should think would be a fair allowance for the cases of general tuberculosis or ulcerative endocarditis, and other general septicemias of various origin.

There are no cities in this country which give really an accurate representation of the proportion of deaths from malaria. The City of Philadelphia would seem to me to give the fairest representation of this question, and that I have already quoted where the deaths from typhoid fever in 1901 were 444, from malaria 15, and from various other indeterminate conditions, 12. I believe the proportion of deaths is too large even there, but it approaches the correct figures much more than I believe any other city which I have examined. In Baltimore we have in 1902 220 deaths from typhoid fever and 31 from intermittent fever, which is supposed to be malaria. I am sure from my observations here that that is an overestimate of the deaths from malaria—from my observations which have been made in connection with the Johns Hopkins Hospital, where we get a

7483 fair general run of cases as they enter the hospital.

It is recognized by all competent observers that such a method of representing the mortality from typhoid fever by classifying fevers under these two headings is entirely incorrect.

Assuming the typhoid and malaria statistics as they appear in the tables from the Board of Health reports of the City of St. Louis from 1895 to 1903, I should regard these tables as indicating that the mortality from typhoid fever had fluctuated more or less from year to year; that gradually in the last three years an improvement in the accuracy in the reports from the general physicians had taken place, so that cases of typhoid fever which had previously been included in column "B" (malaria) had been properly treated as typhoid fever.

As to the relative frequency of typhoid fever and malaria, it would seem to me that it would be impossible to draw definite conclusions from these tables. However, as to the prevalency of typhoid fever I should think that one might draw good conclusions. I should

*This answer is worthy of consideration.

think that the mortality from typhoid fever had varied from time to time, from year to year; had risen slightly during the last two years, but that the fluctuations were no more than such as had previously occurred and were not such as to justify any direct assumption in regard to the cause. In the year 1892 I should suspect that
7485 there had been some definite epidemic, but since that time the variations shown are not such as to suggest to me any direct and special cause. They are variations such as occur in most cities in this country from time to time without exception.

By combining the typhoid and typho-malaria fevers into totals, as in a table assumed in the question, I should regard this table as indicating only variations in the typhoid mortality, such as I have stated a moment ago might and do occur in many cities without any definite explanation being found. The typhoid mortality, I should say, rather decreased, tended on the whole to decrease from 1893 down to 1901. During the two years following 1901 there has been a slight increase, but that increase is not, it seems to me, more than might occur without any special change in the pre-existing
7486 conditions.

The circular letter assumed in the question as being sent out to the doctors of St. Louis, I should say that it certainly did manifest itself in the statistics. It appears in the relative increase in the number of deaths reported in the typhoid column as compared with those in the column of remittent, intermittent, etc., fevers. It would indicate to me that, stimulated by the advice of the Board of Health, the physicians had made more accurate and careful diagnoses. Taking these two columns separately, I do not think they correctly show the typhoid conditions satisfactorily in the City of St. Louis. This is based upon the fact I have already mentioned, namely, that everything in my experience and study goes to show that the diseases included under such headings as these are, in the vast majority
7487 of instances, typhoid fever.

In regard to the wells in St. Louis, I should say that the chances were that they would cause typhoid fever, that such wells would be a menace to the health of the city, and that it would be very possible that certain of the wells might become infected
7488 and serve to spread the disease.

In those cases in which infection of water supplies have been definite or fairly definitely proven, it is always, to my knowledge, manifested by an explosive epidemic. It is common to assume in cities, such, for instance, as the City of Baltimore, where we know our water supply is open to contamination, it is common to assume that

cases are dependent upon the water supply, but as a general rule, where it can be proven that the water supply going to the whole city is infected, there is an explosive outbreak, and it seems to me it would be very difficult to prove the instrumentality of the general water supply to a city in producing typhoid fever, unless such an epidemic occurred.

From a study of the typhoid statistics in St. Louis, they do not indicate an explosive epidemic within the meaning of the an-

7489 swer which I have just given.

Assuming the combination of typhoid fever and malarial fever based upon the population of St. Louis as given in Professor Jordan's table, I should say that this table indicated that during the past two years there has been a slight increase in the typhoid mortality, but that this increase has been preceded by a diminution, and on the whole a gradual diminution, from 1892 down to 1901. I should hesitate from these figures to assert that the mortality had prominently increased, or I might say that to look at such a table I should not regard it as having greatly increased, and I should want to see what happens in 1904 before expressing any opinion. The increase in 1902 and 1903 seems to me not more than might occur with fluctuations such as are observed in the tables which I have mentioned for New York, Brooklyn and other cities. It seems to me that the conditions between 1898 and 1899 are worse than the conditions between 1900 and 1901.

7492 Death rates from other American cities.

From a careful analyses of the statistics of conditions since 1900 for the ten years previous, there seems to me to have been an increase, not a great increase, but an increase. There is nothing in those figures to suggest to me any definite special cause. I must say that I should be inclined, perhaps this is quibbling, to regard in any city with a typhoid mortality such as St. Louis has, or that which we have in Baltimore, to regard typhoid fever as epidemic, but I should not consider the conditions of the last several years in St. Louis such as to suggest that any striking change had taken place in the general conditions that obtained prior to that time. I think it is fair to say that any increase occurring two years in succession should always make one look for something, but I should not regard it as particularly suggestive that the assumptions made in the earlier question in regard to the conditions of wells in the City of St.

7493 Louis are true.

CROSS-EXAMINATION.

Between the years 1896 and 1897 there is an increase of a little over one per cent., but, of course, between 1898 and 1899 there is a definite increase. There is an increase which is comparable
7499 with that which occurred between 1902 and 1903.

I have seen cases of remittent and intermittent fever which were so diagnosticated and were malaria, but people do not die of it. They are cured by quinine. I have seen such cases that do not react with quinine; in a great majority of instances these have been
7501 typhoid fever and never malaria.

JOHN W. HILL.

DIRECT EXAMINATION,

By Mr. Todd.

Hydraulic engineer and chief engineer of Bureau of Filtration at Philadelphia.

Capacity of the plant is 320,000,000 gallons of water every day, filtered from the Schuylkill and Delaware Rivers at a cost of
7502 $26,000,000.

Have been associated with about sixty works of public water supply, looking either to the general construction or improvement of waterworks. Was connected with the water supply of Cincinnati, Markersburg, Madison and Jeffersonville. Have passed upon
7503 streams for water supply for twenty-four different cities.

Have taken up the subject of bacteriology; have also studied the chemistry of waters, not with a view of being a bacteriologist, but with a view of informing myself as to the true interpretation of chemical and bacterial analyses of water samples in connection with my work as engineer in charge of the improvement of the water supply of Philadelphia, and other cities.

Have investigated typhoid epidemics personally and am ac-
7505 quainted with the literature of the same. Am acquainted with sanitary problems in Europe and given special attention to public water supplies. My interpretation of water analyses has covered a period of thirty years. It is my duty to pass upon the technical investigations of our water samples coming to and from our filters, and from them to determine the efficiency of our work of filtration. I have studied the reports of Streams' Examinations and Professor Long's reports in the public health reports of the State of

Illinois, and have studied them especially for four months
7506 during the years 1899 and 1900.

I am acquainted with the Chicago River and the water course from Chicago to Grafton from the literature, and am acquainted with the water conditions at Peoria during the year 1882, when I was employed on the Peoria waterworks.

I have made a special study of bacteriology as applied to water investigation.

7507 Pathogenic and non-pathogenic differentiated.

I have found the bacillus prodigiosus in the waters of the Ohio River during 1895 and 1896. I have made experiments on the longevity of the typhoid in 1895 in sterilized Ohio River water, and in unsterilized Ohio River water. These tests on sterilized river water indicated that the typhoid organism would live for sixty
7508 days; on unsterilized water gave negative results.

In Philadelphia I made an experiment on the longevity of the typhoid germ and the colon bacillus with the unsterilized Delaware River water, with the quantities of chlorine varying from 25 to 300 parts per million, extending over a number of weeks, and revealed the fact that salt had little or no influence upon the longevity of the organism, and that its life history was limited to from five to eight days under the most favorable conditions. Also that the colon bacillus would live longer in unsterilized Delaware River water
7509 than would the typhoid organism.

7511 Description of the experiment.

7512 Table showing results of the experiment.

This test affords me information upon which to base my opinion as to the life of the typhoid in polluted water. In the absence of information to the contrary, I should assume the longevity of the typhoid organism in lake or river water where the sewage pollution was no less than that of the Delaware River at Torresdale,
7515 would be substantially the same as that found here. This test indicates that the typhoid organism, or any suspected water bacteria will live longest in sterilized water, due to the fact that sterilization does not remove the food material, and possibly increases its availability as food for the bacteria, and such material is
7516 consumed only by the organism with which the experiment is being made.

I should feel safe in expressing that opinion that the organism would certainly not live longer in the unsterilized than it did in the sterilized water, and probably would have a shorter life history. The greatest length of time that a typhoid fever organism lived, as shown

by the tables, is eight days. I should anticipate that its life in the unsterilized water would certainly be no longer than eight days, and probably less than eight days by reason of the facts stated in answer to the previous question, with reference to the influence of sterilized water on the life history of the organism with which it may be
7516 inoculated. I regard the laboratory test usually made, and certainly that I have made or caused to be made, as more favorable to the growth of the typhoid organism than it would be in the normal waters.

I should put the life of a typhoid organism in a sewage polluted river water under normal conditions which prevail in the majority of the rivers of the United States drawn on as the sources of public water supply, as from five to eight days. I am now referring to a typhoid organism that would come in from a definite point.

I am assuming as a general proposition that the rivers, when they are the source of our supply, as the Delaware, Schuylkill, Merrimac, the Hudson, the Missouri and the Mississippi, at points of intake for large cities, are not largely different with reference to sewage pollution. There is a distinctive sewage pollution in all those
7517 streams that would have some modifying influence on the longevity of the organism.

From my information in regard to the Illinois River, I should not anticipate a greater longevity of the typhoid organisms in the water of the Illinois River than I have found in the water of the Schuylkill and Delaware Rivers.

I am acquainted with the drainage canal, Desplaines River, Illinois River and the Mississippi, so far as information can be obtained from the publications of the hydrographic journals of the coast survey, together with my personal knowledge of the Illinois River for a short time in my connection with the waterworks at Peoria.

Effects of the dams in the Illinois River upon the problem of sedimentation, and illustrations based upon the dams in the
7519 Schuylkill River and their effect upon purifying that river.

Flood conditions and overflow of lands affecting the problem
7520 of sedimentation, discussed.

The effect of the full flow of the canal on the problems of sedimentation. The effect of dilution on the problem of self-
7521 purification, and the diminishing of infection, discussed.

The water flowing into the Illinois River from Lake Michigan should be regarded as a benefit to the Illinois River.

Basing my opinion upon the tables, chemical and bacteriological, for the months of June, July, August and September, 1899 and

1900, it does not appear that the addition of the sewage of Chicago to the Illinois River is a detriment. The data for the four months of the two years mentioned show the condition of the river below the City of Peoria is better for 1900 than it was for 1899. * * * In giving this answer some account must be taken of the difference of stream flow for the two years, but notwithstanding that stream flow, according to the evidence, was greater for 1900 than for 1899, I still think that the chemical conditions indicate that self-purification is better for the latter year, and having no better data before me it does not appear that the addition of the sewage in Chicago
7522 has injured the quality of the Illinois River south of Peoria.

Basing an opinion upon the technical investigations that have been made for the four months in 1899 and 1900, it would indicate from a chemical point of view an improvement in the quality of the water at Grafton since the opening of the drainage canal. * * * There is nothing to indicate that the danger to public health has been increased since the opening of the drainage canal as far as Grafton. In making this statement I wish it understood that I do not believe that the water of the Illinois River at Grafton before the canal was opened was fit for drinking and some other domestic uses, and my answer must be construed as showing only that the conditions are no worse during the months of 1900, which I have under consideration, than the corresponding months of 1900, prior to the opening of the canal.

I have a compilation of chemical and bacterial data to justify the conclusions just expressed.

7525-28 Tables.

If I was applying the information contained in the sheets showing the nitrates and nitrites for 1899 and 1900 and the percentages of decrease and increase to the work of filtration, I should have no hesitancy in claiming the same degree of purification by the filters as is here shown by self-purification or sedimentation in the channel of the river. * * * Taking all the data together and particularly that relating to the total oxygen consumed and the nitrates and nitrites, I consider that the condition of the water flowing
7529 into the stream at Grafton has been improved. Basing the opinion upon the technical data collected by others for the period of this investigation, I do not think that the sewage of Chicago in its original condition is manifested in the waters of the Illinois River at Grafton. This opinion is based chiefly upon the tables containing the record of the determinations of nitrates and nitrites at the thirty-two stations under consideration.

I do not think that any marked effect would be felt in the combined waters of the three rivers by reason of the combined discharge of sewage and Lake Michigan water into the head waters of the Illinois River at Joliet. The reason why typhoid bacillus will not live as long in polluted water as in pure water is because of the presence in much larger numbers of the strong bacteria of putrefaction
7551 and fermentation which finds a normal habitat in polluted water.

In the light of such information as I have upon the longevity of the typhoid bacillus in unsterilized waters, and of the knowledge with referenec to the conditions subsisting along the Illinois River, I should not expect a typhoid organism introduced into the Illinois River, together with the sewage of Chicago, to pass the entire length of the stream. I should expect it to perish somewhere in transit and probably before it reached the City of Peoria, and the reason for this opinion is based upon the evident rate of reduction of organic matter in the river between the points of discharge into the canal and the City of Peoria, the typhoid bacillus, like other bacteria, being a part of this organic matter.

I am acquainted with the settling basins of St. Louis and have been acquainted with the water supply of St. Louis for twenty years. and taking into consideration the report of J. P. Kirkwood
7533 made in 1866, who was one of the most eminent hydraulic engineers in the United States, and was employed by the City of St. Louis to develop plans for the general improvement of the water supply, who published a report which for many years was considered the most elaborate report on filtration works of Europe that was printed in the English language, I do not regard the settling basins of St. Louis as at present operated a complete guarantee against infection coming from the waters of the Mississippi River, because it is not possible with such limited sedimentation as can be carried on in the reservoirs to so purify an ordinary polluted water as to fit it for domestic uses.

COVINGTON, KENTUCKY, SETTLING BASINS.

I was familiar with the construction at the time these settling basins were built by reason of temporary employment by the contractors and by reason of my connection with suits brought by the contractors against the trustees of the Covington reservoirs. Later I became acquainted with them in connection with my work at Cincinnati, at which time samples were taken from the Covington reservoirs to determine how much, if any, purification was going on by

reason of long sedimentation. * * * The bacterial test of the water in Covington reservoirs compared with the test of the Ohio River revealed a reduction in bacteria of as much as 97 per cent. Because the basins hold a supply for thirty days does not justify the assumption that typhoid bacillus will live in that water for such a period. A large part of the population of Covington does business, or are otherwise engaged, daily in Cincinnati, and from investigation of the typhoid fever rates of the three cities, Covington, Newport and Cincinnati, there is satisfactory evidence to my mind that the larger part of the typhoid in Covington and Newport is chargeable to the Cincinnati water; that is, to the water that was used by the people who were there attending school or looking after business or shopping in the largest city. Notwithstanding the conditions which reflect upon the action of the Covington reservoirs, the typhoid rates are much lower in Covington than they are in Cincinnati.

7535 Typhoid rates of Covington and Cincinnati tabulated.

WELLS.

It is, I believe, the common opinion of sanitarians to-day, and it is certainly my opinion, that an open well is not a safe source of drinking water in an old and well built up urban community, by reason of the fact that soil in due time will become polluted with the waste from privy vaults and cess-pools, and that pathogenic bacteria and perhaps other objectionable matter from such cess-pools and vaults may by the ordinary means find a way into the well

7536 and render such water unfit for drinking purposes.

7537 Mortality percentage method discussed.

7538 Rural and urban population and their polluting effect upon water courses discussed.

Q. If upon a water shed where the water is polluted, there could be many sources of pollution and infection, and typhoid fever should break out in a given community, where would you look for the source of infection?

A. At the nearest possible point of pollution above the source of water intake, or above the point of water intake. * * * Because the nearer the cause of source of infection, the more certain and more virulent would be the outbreak of typhoid. * * * There would be as much danger to the City of Philadelphia through an infection of the water of the Schuylkill River by an outbreak of typhoid fever in Morristown, a city distant about ten miles, with a population of 16,000, as there would be in Reading, seventy miles away, with a population of 80,000. The element of distance from the

point of infection to some extent balances the size of the community, that is, or might be the cause of the infection. * * * And in seeking a cause where this typhoid that is supposed to be due to polluted water supply, the usual step taken is to begin at the water-
works intake, and carefully exploit the causes up stream until
7539 one is reached, if it be reached at all.

Chemistry and bacteriology furnish information on the quality of water that cannot very well be had in any other way. It furnishes direct information along certain lines that cannot be obtained in any other so-called practical manner. As to a typhoid bacillus lying sixty days in the sediment of a stream, I have no opinion whatever upon a proposition of that sort, and do not like to offer an answer to the question. There is no data with which I am familiar indicating any such condition as is recited in the question, and I do not know that I could offer any better reason upon this than that given before with reference to the probable longevity of the typhoid organism in the sediment of a stream, having stated in that answer that the chances were in my opinion that the longevity of the organ-
ism would be less if found in the sediment of a stream where
7541 the processes of organic decomposition were in progress.

COMPARISON OF THE THREE RIVERS.

From a bacteriological point of view the water of the Illinois River at Grafton is decidedely better than the water of the Missouri River at West Alton. Concerning the suspended matter, the water of the Illinois River at Grafton is superior to the water of the Missouri
River at West Alton. The same statement may be made with
7542 reference to total solids, nitrates and nitrites.

Q. If the Illinois River discloses a less amount of impurity than the Missouri, what would be the effect of the waters of the Illinois River emptying into the Mississippi River at Grafton, and subsequently uniting with the Missouri River at its mouth, upon the combined waters of the Mississippi and Missouri Rivers at the intake tower of the St. Louis waterworks?

A. Considering the relatively small natural stream flow from the water shed of the Illinois River when compared with the stream flow of the Mississippi River above St. Louis and the stream flow of the Missouri River, and ignoring or setting aside the fact of the Illinois River being either better or worse than that of the two larger streams, the addition of the ordinary stream flow from the Illinois River to the combined stream flow of the other two rivers would not have much effect either way. In order to reduce this to a more

definite statement I have prepared a table showing the relation and area of the drainage basins of the three rivers mentioned in the question, and assuming for the present that the mean rain-fall would be the same over the combined drainage area of the Illinois, Mississippi and Missouri Rivers, upon this basis, and omitting the flow of Chicago sewage or of sewage from Lake Michigan of each 100 gallons of water flowing in the Mississippi River opposite the chain of rocks, 75½ would come from the Missouri River water shed, 20 1/3 from the Mississippi water shed, and the remaining 4.4 from the Illinois River water shed. As a matter of fact, however, the mean rain-fall over the whole area of the Missouri River water shed is not so great as that over the water shed over the Illinois and the Mississippi Rivers, and it is probable that of the total flow of water of the Mississippi opposite St. Louis, 70 per cent. can be charged to the Missouri River water shed; 20 or 22 per cent. to the Mississippi water shed, and the remaining 6 or 7 per cent. to the Illinois River water shed. In this case it is assumed that no water falls in the Illinois River except that due to the rain-fall on this drainage basin.

Allowing the least stream flow of the Illinois River at Grafton as reported by the United States engineers, October, 1891, of 1,000 cubic feet per second, and assuming the discharge from Lake Michigan through the drainage canal of 300,000 cubic feet per minute, or 5,000 cubic feet per second, and allowing for the discharge of sewage based upon 90 per cent. of 85 per cent. of the total water consumption of Chicago, which produces a discharge of 425 cubic feet per second, the percentage of volume flow with the least recorded stream flow of the Illinois River at Grafton would be 7. Taking this flow into consideration, and also taking into consideration the flow of sewage from Chicago plus the flow from Lake Michigan.

Of the water flowing into the Mississippi River opposite St. Louis 20 per cent. would be credited to the Mississippi River, 75½ per cent. to the Missouri River and 2.96 per cent. to the Illinois River and 1.54 per cent. to the influence of the discharge of Chicago sewage,
or such water as is carried with the sewage into the drain-
7542 age canal, exclusive of the diluting water drawn from the
7544 lake.

Facts upon which the foregoing calculations were made and
7544 the source of information.

7545-49 Tables showing distances and population on water sheds of the Missouri, Mississippi, Illinois, Delaware and Schuylkill Rivers.

Q. Does the mixing of the Illinois with the Mississippi and

Missouri Rivers, as mentioned in the foregoing answer, create any added danger to the already contaminated and polluted waters of the Missouri and Mississippi Rivers at the St. Louis intake, in your opinion?

A. In my opinion, it does not, for two reasons. First, according to analytical data the condition of the Illinois River was no worse during 1900 than in 1899. * * * Second, of the total volume of flow of the Mississippi River opposite St. Louis, by far the smallest percentage comes from the Illinois drainage basin, even while considering the flow of the sewage of Chicago, and the water from Lake Michigan is a part of the discharge from that river. Under these conditions it would be difficult to conceive of the pollution of the Mississippi River at a point below the confluence of the three rivers, excepting the pollution of the Illinois River, was very great, with reference to the pollution of the two other streams which contrib-
7550 uted to the body of water moving past the City of St. Louis.

The information which I have of the Illinois River does not warrant the belief that infected matter from Chicago would be found in the Illinois River as far south as Grafton.

Q. Assuming that typhoid fever germs should be found in the Mississippi River at the chain of rocks, do you know of any way of determining from what source such germs originated?

A. Taking into consideration all the facts and considering the three drainage basins upon each of which are found many cities like Peoria and Chicago on the Illinois, Dubuque, Davenport, Burlington, Des Moines, Rock Island, Moline and Quincy on the Mississippi, and Kansas City, Topeka, St. Joseph and Omaha on the Missouri, in all of which cities typhoid fever prevails during the usual season, and especially keeping in mind the larger cities close to St. Louis, it would be wholly impossible, in my opinion, to say from what city the typhoid fever organisms found in the Mississippi River opposite St. Louis would come. * * * Statistics show that in all the larger cities of the country typhoid fever always prevails, and where the drainage of three water sheds combine as in the Mississippi River in front of St. Louis, I know of no process whereby the typhoid organisms there found could be assigned to the probable locality from which they came.

In regard to typhoid fever germs living for a long period of time in the bottom of the river, the investigation of what is known as the Dayton Sand Bar in the Ohio River north of Cincinnati
7551 is set out.

I do not regard the Illinois, Mississippi or Missouri Rivers as a

fit water for drinking and other domestic purposes prior to the
7552 opening of the drainage canal, nor for many years prior to that.

I do not regard any river water that received sewage as a safe drinking water without mechanical treatment of some kind. The sanitary quality of the Illinois River has improved since the opening of the drainage canal, and is not less sanitary than the waters of the Missouri and Mississippi, and the Illinois River waters since the opening of the canal have had no marked influence on the quality of the combined waters of the Mississippi River passing the chain
7553 of rocks.

If the typhoid statistics of St. Louis show an increase in the rates per unit of population since the opening of the drainage canal and an investigation clearly indicates that there is no other possible source of infection, and the rates in St. Louis rise correspondingly with the rates in Chicago, and fall correspondingly with the rates in Chicago, it might be held that such increase in the unit rates for typhoid fever in St. Louis could be charged to the flow of the sewage through the drainage canal, but in view of the possibility of infection from other urban centers than Chicago, and especially in view of the possible infection of the St. Louis water supply from typhoid fever prevailing in Peoria, I should hesitate to charge to the flow of Chicago sewage through the drainage canal any increased typhoid rates shown in the City of St. Louis since the opening of the canal, unless the evidence clearly discloses the fact that as the rates rise in Chicago they rise in St. Louis, and as they decline in Chicago they also decline in St. Louis. In other words, unless the rates in St. Louis corresponded with the rates in a city supposed to be the cause. I am led to this opinion by the nearness of the City of Peoria, where typhoid fever prevails during the usual season of typhoid, or any other cities of large population upon the water sheds of the Mississippi and Missouri Rivers. While one cannot say positively that the sewage of Chicago might not contribute to this or certainly does not contribute to this, it is equally out of the question to assert that a single city discharging its sewage into one of the rivers constituting the drainage area of the river which went in front of the City of St. Louis intake is the sole cause, or at all the cause of the increase in the City of St. Louis. Too many factors enter into the proposition, such as is contained in the question, to justify one in asserting that typhoid fever is due to any one of several possible centers of infection lying on the drainage basin above the City of St. Louis.

The City of St. Charles being nearer the point of intake than the

City of St. Louis, in my opinion, would constitute a greater menace to the water supply of that city than would the larger City of Peoria, situated five times as far away in point of distance, even
7555 if the normal rate of typhoid in the two cities were the same.

I have always believed, and can point to no evidence that contradicts this belief, that the nearness of the point of infection, rather than the size of the urban or rural center, is the chief factor in determining infection.

From examination of Professor Mason's chart of typhoid fever for 1900 to 1903, inclusive, * * * it does not appear that the typhoid fever death rates from St. Louis are coincident in intensity with the typhoid fever death rates of Chicago. This is especially true for the years 1901 and 1902 and 1903. These years the diagrams show that when the rate is rising in Chicago it is declining in St. Louis, and when it is declining in Chicago it is sometimes rising in St. Louis, and the wide ranges of typhoid fever deaths in Chicago are not reproduced in the death rates for the City of St. Louis, and it would not be possible, in my opinion, to connect the rates in one city with the other. In fact, there might be just as close an agreement between the typhoid fever rates in the City of Chicago and Philadelphia, if plotted together in this manner, as there is between the typhoid fever deaths of the Cities of Chicago and St. Louis, and clearly the typhoid fever rates of Chicago can have in this manner no influence whatever upon the typhoid fever rates of Philadelphia.

WELLS.

As a general proposition wells in built up communities, like the City of St. Louis, are always open to suspicion as possible sources of illness and disease. This is due to the fact, as previously stated in this examination, that the soil will in due time become polluted from organic waste from leaky sewers and connections to sewers, etc., and it is possible that where a well is open to infection from the feces of a typhoid fever patient, it may become the center of infection and cause of widespread disease. This fact is so well recognized in the large cities that there are few cases where wells are still used as sources of drinking water. * * * And the condemnation of open shallow wells or wells sunk in the drift by the local health boards is a matter of frequent occurrence in the larger cities where such wells are known to be still open to use. Personally, I should regard every such well in the City of St. Louis, the water of which is liable to be used for drinking, as a menace to the public health, excepting
7557 the well is so far removed from possible source of pollution

7558 as to be reasonably safe from the contents of vaults and cesspools leaking through the surrounding soil.

FILTRATION.

The water of the Mississippi at St. Louis should be treated by
7558 filtration. In passing upon the question of filtering the water of St. Louis no special consideration would be given to the sewage of Chicago running into the head waters of the Illinois River, which forms one of the tributaries of the Mississippi River.

I have made an investigation of the population living upon the three water sheds, the purpose of the investigation, following the usual custom in determining the probable degree of pollution of water supply of a stream that is drawn upon as a source of public water supply, was to show, first, the distribution of population per square mile, locate the center of gravity; next to relate the urban population on which each water shed to St. Louis has a point of water intake. The first step in the investigation was to divide the total population on the water shed by this area from which is derived the distribution of population per square mile of drainage basin. Next the population of each urban center was divided by the distance of the center from the St. Louis intake. The quotients thus obtained were averaged, and the total population divided by the sum of the quotients, fixing
7559 thus the center of gravity of the population on each water shed.

Further investigations were made along this line, comparing St. Louis with Philadelphia and with Hamburg, in Germany. * * * Following the several methods above mentioned to arrive at the probable pollution on each of the three water sheds contributing water to the Mississippi River at St. Louis, the following results were obtained:

The distributed population per square mile on the water shed of the Missouri River is 9.94; Mississippi River above St. Louis, 43.21; Illinois River, 107. The urban population on the Missouri is 27 per square mile; on the Mississippi 9, on the Illinois 72. Referring especially to that part of this answer in which the statement is made that the respective populations of the urban centers on each of the urban centers of 4,000 or more people are divided by the distance of such centers from the intake of the St. Louis waterworks, and in which the total population has been divided by the mean of the quotient thus obtained, a factor is obtained for each stream as follows:

For the Illinois water shed, 209.2;

For the Mississippi water shed, 122.47;

For the Missouri water shed, 106.56.

* * * * That is to say, the Missouri water shed would have the highest value, the Mississippi next, and the Illinois water shed the least value as the source of water supply for the City of St. Louis. * * * In the calculations just mentioned no consideration is given to the flow of the water in the stream whatever. This statement is entirely independent of the flow of each stream.

The volume of flow would have this effect. If the flow of each of the several streams was an average of same, it would not
7561 change the relation established showing the value of the water sheds as sources of public water supply. * * * If, however, the flow was greatest from the Missouri River and least upon that water shed which is the least desirable, namely, the Illinois River, it would mitigate the objections to the greater degree of normal pollution by reason of larger population and shorter distances from St. Louis on the Illinois River drainage basin. If the flow of the Illinois River was 1 per cent. of the total flow of the Mississippi River, then, notwithstanding the fact that this is the most objectionable drainage basin to draw from, its influence, when compared with the other 99 per cent. of water derived from the Missouri River and the Mississippi River, it would probably not be appreciable.

Applying this information to the question of filtration of the water supply of St. Louis, it would have no bearing at all, because any investigation preceding the development of a scheme of filtration of the water of the City of St. Louis would be devoted to the collection of data with reference to the water flowing past the proposed point of intake, and no serious consideration would be given to the source from which the pollution found in such water came.

I have made a comparison of the conditions of the three cities, namely, St. Louis and Philadelphia with reference to the Schuylkill River alone, and Hamburg, Germany, drawing its water supply from the Elbe River. Assuming that the City of St. Louis drew its water supply from the Illinois River drainage basin.

Considering the total drainage area of each of the three drainage basins, and considering the urban and total population on each basin and developed the factor in the manner explained in my answer heretofore. The size of the numbers thus obtained indicates the objection to each source of water supply as follows: For the City of St. Louis, on the assumption that the water supply is drawn only from the Illinois River basin there is 209.20; of the City of Philadelphia, drawing from the Schuylkill River, 330.63, and Hamburg, from the Elbe, 698.12. The lower figure by this method of comparison would indi-

cate the best source of water supply, and would show that under the present conditions the Illinois River would be a safer source of water supply for the City of St. Louis than the Schuylkill for Philadelphia or the Elbe for Hamburg. The water of the Elbe is now, and has been for eleven years past, all filtered. Preparations are going forward to filter the water supply of Philadelphia from the Schuylkill, as well as from the Delaware River, and by the same process of reasoning it would seem to me that the water supply of St. Louis should be filtered in order to remove any natural objections that exist to the sources from which its water is taken.

It would make no difference whatever, either in the cost of construction or the cost of operation of a system of filters for the City of St. Louis with the water of the Chicago drainage canal entering the Illinois River as it now does. From a reasonable experience in constructing and operating works of filtration on a large scale, it is clearly shown that the sewage pollution of a river is not the
7563 feature that increases the cost of filtering the polluted water. That material which rapidly clogs the filters requires their cleansing from time to time is mud and silt and represented in the analysis as suspended matter, of which the bacteria from the sewage source constitute by weight of volume, an infinitesimal part. It is not known that what we term mud, excluding bacteria, is in itself a particularly objectionable element in water, and the cause of disease or disorder in the human system. * * * I feel that the experience at Philadelphia with the filters dealing with upwards of 23,000,000 gallons of water per day, that the varying degrees of pollution of the Delaware River, as determined by the bacteriological and chemical analyses, have no influence whatever, either upon the efficiency of the filters or their cost of operation, but when the Delaware River is in flood and large quantities of material are brought down, this material does have an influence in affecting the cost of operating the filters, and to a limited extent has some influence on the efficiency.

The Missouri River, by reason of the very large amount of suspended matter brought from its water shed, would create the largest percentage of cost in operating a filter plant at St. Louis, and the difficulty of filtration at St. Louis will be found to be wholly due to the silt and other suspended matter in the Mississippi River water obtained very largely from the Missouri River drainage basin. The sewage content at St. Louis I should regard as involving no special difficulty whatever, and I base this opinion on careful study of the report of the last commission of engineers appointed to investigate

the water supply of that city, made by Allen Hazen of New
7564 York, and others.

The Mississippi River and the Illinois, exclusive of the Missouri River, would not cost as much to filter as the Missouri, for the reason that the percentage of suspended matter is lower in each of the two rivers than it is in the Missouri River. The amount of infection, meaning by that sewage infection, would not create added cost
7565 to the operation of the filters. All the real cost of operating filters is represented by the efforts to remove from a polluted water the suspended matter, exclusive of the bacteria, and that
7566 matter which largely imparts turbidity to a water.

Q. If the water should be highly infected with typhoid germs would the fact that the water was highly infected create any added cost to the construction or operation of the filter?

A. None whatever. The varying of slight infection and large infection would not create any added cost in the operation of such a filter.

The degree of sewage pollution of an infection of water coming to the filters would not be a factor, either in determining their cost of construction or cost of operation. Evidence along this line is best shown by the regular test which I am having made of the raw
7566 water applied at our Roxborough Filter Station.

The chemical and bacteriological investigations show in reference to the City of St. Louis that the Illinois River is the best source of supply, while the physical investigations that has been described show that it is the least desirable source of supply. If we had no chemical and bacteriological data and were approaching the problem as a new proposition, we would fix the center of population of the Illinois water shed nearer St. Louis intake than that of the Mississippi and Missouri water sheds. The method which offers the most accurate way of arriving at the correct judgment of the quality of such a river is the technical analyses of the water itself at any definite point. The sewage passing over the Bear Trap Dam would not be a faction of expense, either in maintenance or operation or in-
7568 stallation of a filter established for the filtration of a municipal water supply of the City of St. Louis.

CROSS-EXAMINATION,

By Mr. Jeffries.

If the filters were not properly cleaned they would fail to deliver the required amount of water by reason of the clogging of the sand

bed at the surface, but would not produce a perversion of the sand bed.

7570 Double filtration.

7571 The entire elimination of bacteria by filters.

The degree of infection of a water would not affect the cost of construction, but it would affect the grade of sand used in charging the filters with filtering material. If the source of supply is known or believed to be materially affected, it should call for a greater amount of vigilance in the operation of the filters. It would require denser beds of sand and more care in the operation than if the whole purpose was to remove the suspended matter, not of a deleterious character or for the purpose of removing simply mud from the water, but this does not necessarily involve either increased

7571 cost of construction or increased cost in the operation.

The pollution of the Schuylkill River at Philadelphia, based

7573 upon the area of the drainage basin and the population, is much more polluted than the combined waters of the Illinois or Missouri and the Mississippi rivers at St. Louis.

Q. If the waters from the Schuylkill and Delaware rivers from where these samples from which those tests were made were taken, should run down the stream with no added pollution or infecting material, and should contain typhoid fever germs, state whether or not it is your opinion that all of the typhoid fever germs would die out within eight days from the time they were deposited in that water.

A. If the water was of normal sewage pollution, I believe they would.

Q. Then would you recommend the water of the Delaware and Schuylkill after it had passed down the stream for eight days from the time typhoid infecting material was discharged into it and it received no additional infecting material, as being free from typhoid fever germs?

A. I believe that it would be.

Q. Would you recommend it as being free from typhoid, although it was found to exist at the end of eight days, and no determinations were made on the ninth and tenth day, while it was not found on the twelfth?

A. Yes, I should, by reason of the fact that on the eighth

7574 day, referring to the test of October 16th, compared with the fifth day the numbers were so largely reduced as to suggest

7575 their total disappearance within a short time after that observation, certainly within less than a day.

Knowing that the filter effluents at this rate are quite as good

as those of lower rates adopted for similar filters in Albany, New York and elsewhere, I do not think, if the source of supply is known to be polluted with sewage or is known to have a higher degree of such pollution than some other source, that this would involve an increased cost of construction or increased cost of operation. It should, of course, involve increased vigilance on the part of the man-
7584 ager of the filters, but this does not necessarily entail increased cost of operation.

Defendant rests.

REBUTTAL.

DR. EDWARD W. SAUNDERS.

Residence St. Louis; practiced medicine twenty-six years;
7587 graduated University of Virginia; in general practice.

I should say that the Widal test is used only in making an early diagnosis of the disease. It may be used for determin-
7588 ing the cause of the disease, but practically I should say for making an early diagnosis.

7589 The test has had no influence upon me in making out death certificates to the Health Department. The Widal test, I con-
7590 sider, is in general use by the profession in St. Louis for about six or seven years.

Q. As a professional man and knowing the profession as you do, state what effect, if any, the Widal test has had upon the profession in signing and making out death certificates to the mortuary office of the Health Department?

(Objected to.)

A. I should say that it has taken a number of cases from the typhoid list and added a number to it, because cases of nondescript fevers which before that time were assigned to the malarial list after that were assigned where they properly belonged, to the typhoid list. On the other hand, there was quite a conglomeration of cases, patients of what the older writers called the status typhosus, or the typhoid state, which typhoid state had nothing to do with true typhoid fever, and these cases were taken out of the typhoid list.

Q. State whether or not the Widal test, or any other practice, has resulted in taking from the malarial list and placing them in some other list besides typhoid?

7590 A. I hardly think so. The Widal test had conduced to the accuracy of the diagnosis and in that way has taken a number

of deaths out of the typhoid list that heretofore were under the head of typhoid before the introduction of the Widal test, and upon failure to secure the reaction of the Widal test, finding death approaching, it resulted in keeping that death out of the typhoid list, which otherwise might have found place there.

Q. What, in your opinion, has been the effect of the Widal test upon the relative number of deaths of typhoid fever in St. Louis since its use, as compared to the same period prior to the use of such test by the physicians of St. Louis?

A. I am not able to answer that question because I have no clear idea in my mind as to what number have been taken out of the typhoid list and what number have been added to it by
7591 the test. The effect of the Widal test upon the typho-malaria in St. Louis since its use, I should say, has been very favorable, and that a much better mortality rate has been obtained than from the same number of cases occurring before the Widal test. Assuming all other conditions tending to recovery were the same, those in which the Widal test is used for an early diagnosis are found to show a better mortality rate.

7592 I remember receiving a circular with reference to reporting typhoid fever. I do not know whether it was received generally by the profession, but I believe it was. I did not hear the circular discussed. The fact that I received such a circular had no effect upon me in reporting cases of typhoid to the Health Department. I was in no way influenced by it and never thought of it in that light. I never heard the object of the circular discussed.

7593 Q. State whether or not, in your opinion, any of the physicians in St. Louis have been in any way influenced by reason of having received these circulars about the time of the opening of the drainage canal, or any other time?

A. I think not.

Q. State whether or not, in your opinion, physicians generally have been influenced by these circulars to report a greater number of deaths from typhoid fever than they would have otherwise reported as due to that disease in the event that such a circular had not been sent out by the Health Department?

A. I think not. A physician certifying that one of his patients dies of congestive fever, I would not have a clear understanding of the case at all. I would not know what it meant; it would not necessarily mean typhoid. I do not really know what a man would
7594 mean by it. A certificate of typho-malaria, I would understand that he died of typhoid complicated with malaria. In a

case reported as remittent fever, I would suspect that he died of typhoid, because indigenous remittent fevers are not fatal. If an infant patient died of convulsions at the outset of an attack, but not if it died after a protracted illness, inasmuch as quinine is a specific remedy for all malarial fevers in this locality, and only those taken off, such as the very young in convulsions or the old in the first onset, those that are liable to be taken off by that cause.

I have no more clear conception of bilious fever than I have of congestive fever; the same is true of malaria, but of simple continued fevers I would say that they were all in the typhoid class.

Q. Unless the patient be an infant?

A. No, I would not even make that qualification, for the reason that a fever which continues for any length of time, if it be malaria, is amenable to quinine, and if not amenable to quinine I believe in the Osler dictum, that any fever that continues a week and is not amenable to quinine, and is not anything else, is typhoid.

Q. Might it not be something else besides typhoid?

7596 A. I hardly think so.

Q. Do you remember any epidemics since that time?

A. Yes, I remember one in the fall of 1894, just before the
7597 opening of the canal, that was local in the west end, or better quarters of the city.

CROSS-EXAMINATION.

The doctors that I have an intimate acquaintanceship with, their methods of treatment of diseases are those I am called in consultation with. I am called in consultation from fifty to one hundred times a year.

7598 Q. How many cases of typhoid fever do you treat in a year, on an average?

7599 A. Well, I should venture to say, just as a guess, the nearest approximation that I could make, I should say from thirty to fifty, somewhere along there.

I am acquainted with the Board of Health statistics of St. Louis.

Q. If it should appear in the Board of Health statistics of the City of St. Louis during the last ten years that they have a group of deaths reported as remittent, intermittent, typho-malaria, congestive and simple continued fevers, and that those deaths amount to something like 200, would that be any reflection upon the doctors of St. Louis in their diagnoses of diseases of that character?

A. Yes, sir, I think the number is a reflection on the diagnoses.

Q. And does not the number of deaths so characterized in the Board of Health report reflect upon the diagnostic ability and carefulness of the doctors who make those reports?

A. Yes, sir.

Q. And if the number of deaths appearing in the typhoid death column and the number of deaths appearing in the remittent, intermittent, typho-malaria, congestive and simple continued fever column were about the same, what value would you attach to the statistics as giving evidence of the typhoid conditions in St. Louis, based upon the typhoid fever death column as they appear in those statistics?

A. Well, I should say that the majority of those cases belonged to the typhoid column.

Q. Would you say that the doctors in St. Louis were employing the Widal test generally if such a condition obtained as evidenced by the compilation of the Board of Health of the city during the last eight years?

A. No, sir, I should say they were not.

Q. Is it not a fact that these practitioners wedded to calomel
7601 and quinine are obstinate in accepting new treatment for diseases?

A. That is the tendency.

MR. JEFFERIES: I will state that we accept the truthfulness of what is shown in the Board of Health reports from the deaths of typhoid fever, but that such deaths contained in the published Board of Health reports is the only statistics that were offered by the complainant.

7602 Q. Assuming that the mortality health reports of the City of St. Louis discloses the number of deaths from remittent, intermittent, typho-malaria, congestive and simple continued fevers during the last ten years to be about equal to those of the typhoid deaths, is there, in your opinion, any more integrity in the reports of the physicians as to the typhoid deaths than there would be upon the remittent, intermittent, typho-malaria, congestive and simple continued fever death columns?

A. Well, that is a hard question to answer. I would say perhaps the typhoid column is as inaccurate as the other column. That is just a guess or opinion.

Q. If the typhoid column is as inaccurate as the other col-
7603 umn, to what do you attribute the inaccuracies?

A. To failure in diagnosis.

Q. Are the doctors in general practice in St. Louis possessed of that degree of skill necessary to make that diagnosis?

A. No, sir.

Q. That is true of typhoid fever, is it not?

A. Yes, sir, that is true of typhoid fever.

Q. So that in diagnosing typhoid and malaria fever it requires an expert knowledge on the part of the diagnostician to accurately distinguish those fevers, does it not?

A. Yes, sir, in a great many cases; I would not say in all.

Q. And that knowledge is not possessed, is not possessed equally by the physicians in the larger cities, such as St. Louis?

7605 A. That is true.

Q. If it should appear that prior to those years given there were more or about equal intermittent, remittent, typho-malaria and congestive fever deaths in St. Louis than typhoid fever death rates, would the death rate column fairly represent the typhoid condition, in your opinion, excluding the year of special epidemics?

7607 A. No, sir.

Q. How does the fatality for malaria fever compare with typhoid fever in your practice?

A. In my practice, well, I do not think I have ever written a death certificate from any sort of malaria fever except in the very young, when a convulsion carried off the patient in the onset, or in the very aged, where malaria carried off a very weak person.

Q. Assuming that a circular should have been sent out in the City of St. Louis to all of the 1,600 doctors, local practicing physicians, and assume also that the public press was discussing the question and the effect of the drainage canal upon the water supply of the City of St. Louis, and assume that the remittent, intermittent, typho-malaria, congestive and simple continued fever column might decrease during the three years and the typhoid column increase, would the fact of such an increase be manifest in the statistics of the Board of Health, in your judgment?

A. If those are all the facts upon which I am to base this

7609 judgment, I would say, yes. I do not know that I have all the facts.

Q. Is your acquaintanceship with the epidemic of 1899 sufficient to enable you to state what the cause of that epidemic

7611 was?

A. I never came to any conclusions about it at all.

DR. WASHINGTON E. FISHEL.

A physician practicing since 1874. Educated in St. Louis,
7612 Berlin and Vienna. Engaged in the practice of internal medi-
cine. Connected with St. Luke's Hospital in St. Louis. Fa-
7613 miliar with the Widal test. It is used to establish diagnosis of typhoid fever as early as possible.

The effect of the Widal test is to lessen the mortality from typhoid fever. There would be more deaths from typhoid fever without the Widal test than with it.

Q. Doctor, do infants and old people die of typhoid fever?

A. Yes, sir, that does happen.

Q. Is it prevalent among infants and old people?

7614 A. No.

Circulars have been sent out by the Board of Health for a period of fifteen years at least, and perhaps longer, which makes it obligatory on the part of the physicians to report a number of the infectious diseases, and among them typhoid, and has a punishment a fine, when the physician neglects to respond to their ques-
7615 tions.

The effect of the letter, I believe, was that many cases of death from typhoid have not been reported as typhoid, for the reason that if the physicians had reported these deaths as typhoid the Board of Health would have at once demanded an explanation of them why they had not reported it as typhoid before the death of the patient. That is true, I believe, ever since the circulars have been issued.

Q. Suppose a physician certifies that one of his patients dies of typho-malaria, or intermittent or malaria, or bilious fever, or simple continued fever, or any of the nondescript fevers sometimes assigned by physicians as causing death, would you consider that such deaths so assigned were caused by typhoid fever?

A. It would depend a great deal upon the physician who returned the cause of death. When a death is reported as remittent or intermittent, it is not necessarily typhoid fever; it may be any of the diseases which have a fever as a symptom, such as consumption, ordinarily called tuberculosis; that would perhaps explain it best, for tuberculosis has fever as a clinical symptom. You may have pneumonia with remittent or intermittent, any infectious disease that has fever as a symptom, may have a remittent fever type. Meningitis is an infectious disease; so is diphtheria, and that may have a remittent fever.

Q. Suppose the death be reported as being caused by typho-malaria, what would you say to that?

A. I would say that in my judgment there is no such thing as typho-malaria.

Q. Do infants and old people die of typhoid fever?

A. I think that is entirely possible.

Q. Are they as likely to die as middle aged people?

7617 A. If they get typhoid, they are more likely.

The effect of the opening of the drainage canal, I am quite sure that it made me extremely careful in my diagnosis, because naturally I felt that there was great danger of the sewage of Chicago contaminating our water supply, and I wanted to make it at least clear to myself whether in my experience that danger existed, and therefore never reported a case as typhoid when the Widal was not positive and if I may go on, I believe that before that time it was entirely possible that I reported cases of typhoid that were

7618 not typhoid.

I think the opening of the canal had the effect of making the physicians of St. Louis more careful in excluding the possibility of death from other diseases. At present I report no death as due to typhoid in which the Widal agglutinative test has not been found positively, previous to the issuing of the circular, and the penalty which it conveyed to physicians neglecting to report typhoid cases, the cause of death was frequently reported as typhoid when it might have been due to other diseases.

7618 CROSS-EXAMINATION.

Q. And the converse of the proposition is true, is it not, that many deaths from typhoid were reported as other diseases that should have been reported as typhoid prior to the opening of the drainage canal?

A. I think that is entirely possible. I think mistakes of diagnosis were made before we had the positive test for a given disease.

Q. How would you account, doctor, for the number of deaths under the heading, remittent, etc., fevers, as evidenced by the Board of Health reports prior to January, 1900?

A. That would be purely speculative if I answered that. I think many of these cases may have been tuberculosis. * * *

Q. Taking the number of intermittent, remittent and typho-malaria deaths that have appeared in the Board of Health reports of the City of St. Louis during the last six or eight years, would you say that those do not represent more typhoid than consumption?

A. I believe they represent more typhoid than consumption.

Q. The number of deaths as represented by typhoid would be a very small percentage of those prior to 1900, would it not?

A. Yes, I think that is probably correct.

Q. Now, if the circular after the opening of the drainage canal could have an effect upon you, a doctor of recognized standing in the profession, to be more careful in your diagnosis of typhoid, would it not have an equal effect upon doctors less qualified and competent than yourself in reporting typhoid cases?

A. I think on the whole it has made the physicians of this city more careful in reporting typhoid cases.

Q. And if the Board of Health report should disclose that the number of typhoid fever deaths have increased since the opening of the drainage canal, and the number of intermittent, etc., fever deaths have decreased since the opening of the canal, that would evidence the effect of that letter after the opening of the canal upon the physicians of the city in making more careful diagnoses, not only of typhoid fever, but of other diseases, would it not?

A. It certainly would of typhoid fever, and I think of other
7620 diseases. I think physicians are more careful than they have been. * * * I think in regard to typhoid fever the chief
7621 reason for their having become more careful was the penalty attached by the Board of Health in case physicians did not report typhoid fever.

Q. But when you find a number of deaths aggregating in the neighborhood of 200 in a city the size of St. Louis reported under the heading of intermittent, etc., fevers, does not that lead you to the conclusion that there are a great number of doctors in the City of St. Louis, the same as in every other large city, that are not abreast of the profession?

A. Certainly.

DR. LUDWIG BREMER.

DIRECT EXAMINATION,

By Mr. Jeffries.

7623 A physician. Studied in Strasburg and Zurich, Switzerland, Paris and Berlin.

Q. What, in your judgment, doctor, has been the effect of the Widal test upon the relative number of deaths from typhoid fever in St. Louis since its use as compared to the same period of time prior to the use of the test by the physicians?

A. I do not know of any effect. The purpose of the Widal
7625 test is to make an early diagnosis. The earlier one knows that he has to deal with a case of typhoid fever the sooner proper measures can be resorted to, and the more powerful drugs, such as quinine, can be avoided.

Q. And therefore mortality from typhoid fever would be reduced?

A. Well, I do not know that it would be reduced, but the patient is placed under more favorable conditions for recovery. I gather from the talk with the physicians and from hearing
7626 my patients talk about it and the cases occurring in their families; I could not state that there has been an increase positively, but that is my impression, that there has been an increase. That is my impression that there has been since the opening of the drainage canal. I base my impression upon conversations with physicians and others, with the relations of the sick of typhoid
7627 fever patients, and conversations with druggists. I think it is the general consensus of opinion that there has been a gradual increase in the number of cases of deaths from typhoid fever since the opening of the canal.

CROSS-EXAMINATION.

By Mr. Todd.

I do not know how many cases of typhoid fever were in the City of St. Louis prior to the opening of the drainage canal for the period of four years. I do not know how many cases of typhoid fever were in the City of St. Louis during the last four years. I have made no comparison of the typhoid fever statistics of the city Health Department of the City of St. Louis for the last eight years.
7626 Typhoid fever in St. Louis is not distributed in all localities. It may appear in some localities more frequent, and it does not in others, and it may be due to local causes. In figuring out the question of increase of typhoid fever, based upon my impressions, I did not take into consideration the increase in population during the last four years, due to the influx of people here attending the Louisiana Purchase Exposition. That might be included as a factor, I think.

7629 Q. In the diagnosis of typhoid fever, do you use the Widal test in all cases that you treat?

A. I never employ the Widal test myself now. I used it simply for scientific research to find whether there was something in it

when it was new. I am not sufficiently familiar with the ways of the general practitioners as to whether they fail to resort to the Widal test or not, and, therefore, I could not answer that question.

Q. In the diagnosis of typhoid fever it requires a skilled physician to make an accurate diagnosis of most cases, does it not?

A. I do not know; a general country practitioner that has not had much medical training can make out a case of typhoid fever after the second week, even if that man has not had much medical training. You mean is it very difficult? Well, I say it is not from the general appearance and symptoms of the disease, but that is my private opinion.

Q. Those fevers which are called by doctors as remittent, intermittent, typho-malaria, congestive and simple continued fevers,
7631 if diagnosticated according to modern conditions and advanced medical learning would be classified either as malaria or typhoid fever, would they not, in the majority of cases?

A. I would not say that with such a precision. I would say that, no doubt, being entirely unrecognized or mistaken cases of typhoid. I do not know what percentage.

Q. In the treatment of typhoid fever patients it is as much in the nursing and care as it is in the medicine, is it not, doctor?
7632 A. Probably in the nursing. Some doctors are strong believers in medicine; I, personally, do not believe much in medicine.

RE-DIRECT EXAMINATION.

7633 The use of private filters has increased very materially on the advice of physicians during the last six or seven or eight years.

DR. ALBERT E. TAUSSIG.

DIRECT EXAMINATION,

By Mr. Jeffries.

7637 A graduate of Smith Academy and Harvard University; studied in the University of Berlin, taking clinical and laboratory
7638 work.

I am acquainted with the epidemic of St. Louis in 1899, and it was rather sharply localized, I think, in about the central part of what is called the west end.

7639 Filters and boiling water are used a great deal more than they were the past ten years. It is steadily on the increase.

I received circulars from the Board of Health, and the effect they had upon me was that they might have made me a little more observant of my duties; where otherwise I had a case of typhoid fever I might neglect to report it as such, and the effect would be, doubtless, that I should report a greater number of cases of typhoid fever. I do not think it could possibly have any influence on the death certificates that I should write, for that depends on my diagnosis.

CROSS-EXAMINATION.

By Mr. Todd.

Q. How long has the necessity for the boiling and filtering of the water in the City of St. Louis, in your opinion, doctor, existed?

A. I think it has always been a wise precaution to boil the water, or at least since it seemed probable that typhoid was a water-borne disease.

Q. Was, then, the condition that obtained in the City of St. Louis during the last ten years one such as to require the water to be boiled and filtered to prevent typhoid infection?

A. During at least that time it has been a wise precaution. That precaution was emphasized by the typhoid epidemic in 1899; that caused a great many people to begin the systematic boiling of water who had not done so before.

Q. If it should appear in the Board of Health reports of the City of St. Louis that there were only about 200 cases reported under the head of remittent, etc., fevers, and it was not recognized by the advanced physicians in St. Louis that these diseases so named are definite types of disease, to what would you attribute the deaths so reported?

A. I do not think that any man can possibly tell, assuming to a certain extent that it is probably true that a large proportion or a certain proportion of these cases are so diagnosed because the physician in charge does not know what he is about, then I do not think anybody can say what they were. Some were typhoid, some
7644 were consumption, and some probably still other diseases, but I could not say what they were.

Q. If such a proportion of deaths should be wrongfully diagnosed as intermittent, etc., fevers, as is evidenced from the Board of Health reports, would not such a diagnosis reflect upon the ability of the physicians sending in such causes of deaths from diseases which could be properly diagnosed if they had sufficient skill to do it?

A. Why, certainly.

Q. Do you know of any one, any expert or authority, that recognizes congestive fever as a type of disease, or is able to tell
7646 what it means?

A. Well, I think they would prefer to use the word pernicious malaria, as being less ambiguous.

Q. If the doctors would diagnose tuberculosis under the heading of intermittent, remittent, congestive and simple continued fevers, why would they not diagnose typhoid fever under that head, the same class of doctors?

A. I do not think they are very apt to diagnose deaths from
7651 tuberculosis under those heads. Ordinarily when a patient dies of that disease it is pretty clear. I hardly think any really first
7653 rate man would be apt to use those terms, for he would be conscious of their ambiguity. It would be used by the physicians who are not up to date, and all physicians of St. Louis are not up to date.

RE-DIRECT EXAMINATION.

Q. At what ages are persons most likely to contract typhoid fever?

A. On the whole, it is a disease of maturity or middle age, though both the very old and the very young do have it. Just
7655 how frequent it is in infancy is still a matter of considerable dispute.

Q. Is it your opinion that the ordinary doctors, generally speaking, are sufficiently skilled as to make very few mistakes in the
7657 diagnosis of deaths from typhoid fever?

A. Yes, sir; I think I can answer that by yes; I think the mistakes must be few, certainly as compared with many other diseases.

DR. CHARLES H. GOODMAN.

DIRECT EXAMINATION.

By Mr. Jeffries.

Physician of St. Louis; graduate of Yale, Philadelphia Medical College and the Homeopathic Medical College of Missouri.

I think the Widal test has enabled physicians who have had these cases to distinguish between deaths from typhoid and deaths from other causes, by reason of their ability to give proper early treatment; it has enabled physicians to trace the cause of death to typhoid that possibly they might not have done otherwise; and therefore

7659 the death rate by means of the Widal test has been somewhat reduced, I believe. When a patient dies of typhoid fever, as a general proposition, there is no difficulty in making out the cause of death; that might be a matter of experience. I do not think I should have any trouble in diagnosing a case that died of typhoid fever after death if I had the history of the case and the gen-
7660 eral run of the symptoms. * * * I believe I could diagnose a case of typhoid fever even without the test after death.

The letter sent out by the Board of Health made no difference at all with me. The opening of the Drainage Canal had no effect upon me in making my reports of death. I simply wished to see what the increase in typhoid might be at the time, but I do not even remember now what the results were.

The physicians of St. Louis, throughout the city, as far as my acquaintance with physicians goes, recommended to patients and families under their care the filtration and boiling of water. Do-
7662 mestic filters are more generally in use now than six or eight years ago. So far as the moderate cleaning of the water is concerned, the domestic filters are satisfactory, but as to clearing it of the germs or rendering it any more suitable for drinking purposes, I have my doubts.

7663 I am acquainted with the epidemic of 1899 of typhoid fever. It was localized in the west end portion of the city.

Q. Doctor, at what age are people most susceptible to typhoid fever?

A. From ten years up.

Q. Do not children and old people—are children and old people as subject to that disease as middle-aged people?

7664 A. Not as far as I have observed.

CROSS-EXAMINATION.

By Mr. Todd.

Of the number of doctors turned out from our medical school, a comparatively small proportion have had any experience in hospitals.

Q. It is not the common experience of older physicians that any doctors, when turned out of a medical school, while they are able to pass the examination from the text books, are inexperienced in the treating of cases?

A. That is undoubtedly so.

Q. Doctor, when you mean that any ordinary physician can diagnose a death from typhoid fever, do you include in that men of equal

standing with yourself, or the young men that have gone out from the medical college without any hospital experience in the last five or six years?

A. Only men of equal standing with myself.

Q. It is a difficult matter for the best of doctors to diagnose
7666 a case of typhoid fever, is it not?

A. At times.

I do not recognize intermittent, remittent, typho-malaria, congestive and simple continued fevers as distinct types of dis-
7666 ease.

Q. These terms are characteristic of certain diseases rather than the disease itself?

A. That is true.

Q. It may be typhoid, it may be malaria or some other disease which has a remittent, intermittent, congestive or simple continued fever symptom?

A. Yes, sir.

Q. What other diseases are as prevalent in the City of St. Louis as malaria and typhoid that possess these symptoms?

A. None that I know of.

Q. Would the experienced physician without hospital training be liable to confuse typhoid with malarial fever?

A. He might; yes, sir.

Q. If in the health reports of the City of St. Louis there should appear tabulated as deaths occurring from intermittent, etc., fevers, a number of deaths in excess of the number of deaths from typhoid fever, and as you state it you do not regard intermittent, remittent, etc., fevers as distinct types of disease, what, in your opinion, did the people so charged with dying under the head of intermittent, remittent, typho-malaria, etc., fevers, die of?

A. They may have died of typhoid fever; they must have been confounding the terms, or confounded the diagnoses of cases.
7668 I should think. I do not know of any such fatality from malarial fever.

Q. In comparing the groups of typhoid with the typho-malaria, etc., do not those statistics show that the doctors, in reporting typhoid conditions in the City of St. Louis, reported cases of typhoid deaths under the typho-malarial group?

A. Yes, I believe they did at that time.

Q. That was before the day of the Widal test?

A. Yes, sir.

Q. Since that time, in the number of deaths appearing as being

reported by the physicians of St. Louis to the health department under the heading typho-malaria, remittent, intermittent, congestive and simple continued fevers, can those fevers be accounted for in any other way than that typhoid fever has been wrongfully diagnosed as something else, and so reported, in your opinion, assuming that the figures that we have collected have been sworn to and verified as true in the record?

A. Well, as far as they are true, I certainly do, on the supposition that these figures were correct, I will say that the reports may have confounded diseases; those that were reported as typho-malaria may have been typhoid or typho-malaria, congestive, remittent or intermittent.

Q. But, assuming that these statistics that I have collected are properly compiled from the reports of physicians placed with the Health Department of the City of St. Louis published in their final reports?

A. Yes, sir.

Q. Can the number of deaths reported under the heading of intermittent, etc., fevers be accounted for in any other way than that typhoid fever has been wrongfully diagnosed under these various headings?

A. No, sir.

Q. Can you account for the 148 deaths from typho-malaria in 1899 under any other supposition than that typhoid fever has been wrongfully diagnosed under some of these different headings?

A. No, I cannot, unless that, possibly, these physicians might have been mistaken in their diagnoses, and not used the Widal
7670 test. The Widal test is used by some doctors; I do not believe it is used by all in the City of St. Louis.

Q. Now, while that letter sent out by the Board of Health had no effect upon you, are you prepared to state that it had no
7671 effect upon any of the doctors that practice in the City of St. Louis?

A. No, sir.

Q. Assuming the typhoid conditions and typho-malaria conditions from 1896 to 1903, can you account for the decrease in the typho-malaria column and the increase in the typhoid fever column since 1900 in any way except that the fevers which had heretofore been diagnosed as intermittent, etc., have been diagnosed as typhoid fever and placed in the typhoid fever column, when heretofore
7672 they were placed in the typho-malaria column prior to 1900?

A. No, sir.

A discussion between Mr. Todd and Mr. Jeffries concerning
7673 the agreement in regard to the admission of the health reports of the City of St. Louis.

Q. Then, how do you account for the large number of reported deaths under the typho-malaria column and the small number since 1900?

A. Mistake in diagnosis.

Q. In what way was the mistake in diagnosis, in your opinion?

A. Classifying those diseases under typho-malaria that were
7676 probably typhoid.

Q. If a doctor treated a patient for a disease which he called intermittent, etc., any one of these, and the patient should die, would he not issue the death certificate for the disease he thought the man had?

A. I should think so.

Q. Is not that true, evidenced by the fact that doctors do do that because of the number of deaths reported in the Board of Health reports of the City of St. Louis as occurring under
7678 those different heads?

A. Yes, sir.

HERBERT E. SMITH.

DIRECT EXAMINATION.

By Mr. Jeffries.

7679 Dean of the Medical Department of the Yale University. Qualifications.

I was the first to import bacteriological apparatus into this country. I made a number of bacteriological examinations of samples of water that are submitted for that purpose by the county officials principally. I am a chemist and bacteriologist, and am familiar with the methods and results of chemistry and bacteriology as applied to water; also with the subject of river's pollution, having had it brought to my attention in the early part of my work through the practical work which was inaugurated by the State Board of Connecticut in the work which they were pursuing on rivers' pollution, and that was continued up to the present time.

In a general way I am familiar with the various investigations that have been made bacterially and chemically on the subject
7681 of rivers' pollution. Have investigated various epidemics of typhoid fever.

I was appointed as lecturer on the interpretation of water analyses in the Sheffield Scientific School of Yale University about three years ago and have continued to hold that position and give instruction to the class in sanitary engineering in that branch.

7683 I would state that the figures represented in those tables (Tables A, B, C, D and E of Professor Kinnicutt's testimony) do not furnish sufficient data to permit me to form a positive opinion as to the value, as a sanitary apparatus for the purification of the sewage of the Drainage Canal. The figures do show that there is a considerable solution of the suspended matter; that there is a considerable decomposition of the organic matter; that there is the development of a considerable amount of free ammonia. These changes are such as are found taking place in sewage which is stored by the agencies of bacteria. The tables also show that there is a considerable reduction taking place in the various ingredients in the sewage in passing through this canal. In so far, there is a removal of the polluting material from the sewage, but in an important element of the discussion these tables are incompetent to form an opinion as to the destruction of the pathogenic organisms, particularly the typhoid fever, and there is no data with which I am acquainted which will give a true value to the extent to which bacteria may be destroyed or are destroyed in such an apparatus.

The experiments which have been made tend to show that there is a reduction of the typhoid bacilli under such conditions, but how efficient such an apparatus is, it is impossible to state.

(The question to which this answer was given was objected to for the reason it was not competent for this witness to pass judgment upon whether Professor Kinnicutt could pass an opinion such as is asked in the question or not. Also, the witness states that it is not sufficient to permit him to form an opinion, and then he proceeds to express an opinion.)

Q. Assuming at the times the analyses upon which Professor Kinnicutt's tables are based, there was was nothing but concentrated sewage in the canal, state whether or not, in your opinion, these mean averages would not have shown a greater reduction than they do show, owing to the fact that there was a 250,000 cubic feet of water dilution from Lake Michigan?

A. In my opinion the introduction of a larger quantity of
7685 water discharged would tend to reduce the purification that would take place in an apparatus of this sort,—I mean the Drainage Canal.

(Showing the witness Kinnicutt's tables, 41 to 53, inclusive.)

Q. I will ask you to state what conclusions you draw from these tables and what these tables of mean results show with reference to the condition of the stream at these points as to its average pollution at all times of the year?

(Question objected to as not rebuttal or impeachment.)

A. These results show the average composition of the samples of water at the times and places at which they were collected. The several samples show that in the upper portions of the water-way there was a very high chemical and bacterial pollution; that there was a gradual diminution in the amounts of the various chemical constituents in the progress down the river, and that there were certain places where there was an increase in these constituents. The figures of the samples taken at Grafton show that there was in those samples a very considerable evidence of sewage contamination still remaining. There was some variation in this diagram, also, in bacteria, the number at the Grafton station being somewhat higher than at the Kampsville station, for instance. The table fails to show the true condition of the river at these several stations at all times, because the samples taken from a running stream from time to time cannot, of course, show the composition of the river at that place at other times; and, further, there is no evidence in these tables that the samples taken at the time they were taken were proportional to the flow in the river, and, obviously, they would represent a different proportion of the constituents in the river at times of flood from what they would at the time of low water, the samples being of the same size.

7687 (Kinnicutt's tables, 57-64.)

Q. I will ask you to examine these tables and state whether or not from the mean results shown by them positive conclusions can be drawn as to the sanitary condition of the water in the river at those points at all times in the year?

A. In my opinion these tables do not show the condition of the water in the river at the several points at all times of the year, for the reason that the samples were taken occasionally and not continuously; that they did not, as far as the samples show, take into consideration the flow at the time the samples were taken, and that in general an average of this sort cannot show the condition of the stream at other times than those at which the samples were taken.

(Kinnicutt's tables, 1-12.)

Q. I will ask you to state what, in your opinion, is the value of these tables as to their showing the sanitary condition of the water in the Illinois River at all times of the year?

7688 A. In my opinion these tables fail to show the condition of the water in the river at all times and seasons for similar rea-
7689 sons stated in my answer to your last question.

Individual samples taken from Streams Examinations showing varying results.

GENERAL AVERAGES.

The general average does not show a true condition, because the general average can only relate to the conditions at the times and places when and where the samples were taken. In a stream of running water which varies in volume it is very important that the samples should be taken in such volume as will indicate the relative flow at the time the samples are taken. For another reason a sewage contaminated stream varies greatly from time to time in its content of impurity, depending largely upon the irregularities in the discharge of sewage, at one time the sewage being of a certain character, at another time differing widely from it. There is a very marked difference in the flow of streams. * * * For these various reasons an average result cannot show the condition of the stream at all times.

Q. Doctor, in the present developed state of sanitary science state whether or not a table of averages such as were intro-
7690 duced by Prof. Kinnicutt are considered by the scientist as sufficient to enable one to make a competent determination of the sanitary condition of water in a running stream.

(Question objected to as incompetent.)

A. In my opinion the table of averages which are referred to as having been introduced by Prof. Kinnicutt do not form a competent basis in the present condition of sanitary science to permit a definite opinion as to the sanitary condition of the stream to which they relate.

I base my answer first upon the reasons already assigned, when a general average cannot be taken as representing the general character of the stream to which they relate at all times * * * upon my belief that chemical analyses do not and cannot show all the evidence of dangerous pollution which may exist in a stream. * * * In the present state of the science it is impossible to decide whether certain results are or are not evidence of sewage contamination, and further, that there are certain ingredients which may be present in a stream coming from sewage and which are not of material importance which are not revealed at all by the chemical analyses.

In my opinion, therefore, the chemical analysis alone is not a

sufficient basis to decide whether a sewage polluted stream contains dangerous elements of sewage.

Further, I base my opinion upon my belief that in the present state of sanitary science the bacteriological analysis does not reveal in all cases the presence of these constituents of sewage which are dangerous, and further, neither the chemical nor the bacteriological analyses alone, nor both together, can be absolutely relied upon to show the presence in a stream of those substances which may come from sewage, and do come from sewage, and which are dan-
7692 gerous.

(Answer objected to, as it is a contradiction of the testimony introduced in evidence by complainants.)

From my examination of the results given in the tables in the book Streams Examination, and of the tables of averages based thereon, I would say that I am unable to state that all injurious ingredients have been eliminated from the sewage. I have seen the figures of population residing on the water shed of the Illinois, I have
7693 examined the figures showing the amount of sewage discharged into the Illinois River at various points upon its course; I have examined the figures of the Illinois River at the points mentioned, which figures were given by Prof. Van Ornum and Isham Randolph.

Taking into consideration the urban population upon the several watersheds tributary to the Illinois River, exclusive of that of the Chicago Sanitary District, I will state it as my opinion that the results shown in the tables in the examinations of streams, and in the tables of averages based upon them, show that at the times when these samples were taken there was more evidence of sewage than I should expect in a river of this size and population.*

(Objected to as part of the original case.)

Q. State whether or not, in your opinion, Doctor, the chemical and bacteriological data found in the tables contained in Streams Examinations and the tables introduced in evidence by Prof. Kinnicutt show more or less any such bacteriological and chemical constituents which are usually considered as evidence of sewage than which you would expect in event the sewage from the Sanitary District of Chicago was not discharged into that river, the same volume of water flowing down the river in each event.

A. In my opinion the tables referred to do show there was at the times when the samples were taken more evidence of sewage

*Witness is able to express an opinion upon the tables notwithstanding his former answers.

contamination than I should expect to find from the urban population on the watersheds tributary to the Illinois River, exclusive of the waters of the Chicago Sanitary Canal.

7694 In answering your question I have taken into consideration the assumptions and statements made, and would state it as my opinion that the conditions assumed and stated to be present in the river prior to the opening of the drainage canal were such as would afford greater facilities for the removal of pathogenic organisms than those conditions which exist since the opening of that canal, and further, I would state as my opinion that the data furnished by the tables in the book of Streams Examinations and the tables

7696 based thereon do not furnish data for determining the extent to which these pathogenic organisms have been removed.

In my opinion the data furnished in the tables (Kinnicutt) show that there has been considerable removal of the polluting material introduced into the river from the sewage of Chicago, but that they are not sufficient to determine that the purification from the dangerous elements in the sewage has been complete at all times and all seasons.

Basing my opinion upon the results of the chemical and bacteriological analyses which have been furnished and the tables referred to, and upon other data within my knowledge bearing upon the subject, I will state it as my opinion that the sewage is not purified from the harmful agents at the time it is discharged from the drainage canal.

ORIGINAL CASE.

(Complainant's asked of the witness the same questions which were asked of their other witnesses on direct examinations, and which questions were objected to as part of their original case.)

I will state it as my opinion, based upon the facts which you have stated, that the water at the Chain of Rocks is less avail-

7698 able for sanitary use than it was before the opening of the sanitary canal, and then there is a very much greater liability of infection of typhoid bacilli for persons drawing water from that portion of the river.

In my opinion an increase in the flow of the Illinois River as assumed would very largely increase the liability of the infec-

7699 tion of persons drawing a water-supply consisting in whole or part of water from the Illinois River.

Replying to your question, I will state that there are factors in my knowledge which would lead me to believe that the Illinois River was infected by the sewage of Chicago, and that the mingling of this

water with that of the Mississippi River and Missouri River is a most serious menace to the health of persons living below the mouth of the Illinois River.

7700 Replying to your question, and taking into consideration the statements made in it, I will state it as my opinion that I do believe that typhoid bacilli from the sewers of Chicago are liable to find their way into the water-supply of the City of St. Louis through the intake at the Chain of Rocks.

Taking into consideration the statements made in your question, I will state it as my opinion that I would believe that the introduction of the sewage from the City of Chicago has rendered the water of the Mississippi River less wholesome as a supply of drinking water.*

To form a competent opinion as to the sanitary condition of a water and its suitability for use as a supply of drinking water, one should avail himself of all knowledge obtainable on the subject. A chemical examination may give such results as would indicate that the water is sewage polluted. The discovery of such evidence must always make such a water to be regarded with suspicion. To decide the importance of the suspicion one must determine the condition and the extent as far as possible from other means as to the extent and nature of the pollution. Regarding the bacteriological analyses, I will say that it is frequently possible to obtain results which also indicate the presence of sewage contamination, and that such evidence must always render that water suspicious, and that the importance of the suspicion must be determined by a thorough examination as to the source and nature of the source of the pollution. * * * Bacteriological tests have frequently failed to show the evidence of sewage contamination positive in streams which were known to have received sewage contamination. * * * In determining whether a water in use has been a subject of sewage pollution unquestionably the most positive way of obtaining evidence is a careful study of the effects which have been produced by the water upon the persons who have used it. Where a community uses a water which has been sewage polluted, and the injurious ingredients of the sewage still exist in the water, it is inevitably shown in its results upon the health of the people. This is so much the case that the statistics of typhoid fever in a community is on the whole the best evidence which pertains to the fact of sewage pollution. I would state, therefore, that in my opinion the best test which can be applied to decide whether a

*The foregoing answers are in response to questions that were put to complainants' witnesses on direct examination on making out their original case.

given water has been infected by sewage is to study the ty-
7702 phoid statistics of the community using the water.

The following answers are to questions plainly incompetent, because the same questions were asked by complainant of their witnesses in putting on their case in chief.

I will state it very positively as my opinion that typhoid bacilli living in the sediment of a polluted stream for the period of sixty days would be able to produce typhoid if taken into the human system.

I will state it as my opinion that I believe when typhoid bacilli are deposited in the bottom of the Desplaines or Illinois River between Chicago and Peoria for thirty or forty days they might
7703 retain their dangerous qualities as well as their pathogenicity, for I know of nothing which would make certain that such an organism would meet with any material which would be certainly destructive to it under certain conditions.

I will state it as my opinion that sewage from the City of Chicago passing through the course described in the question would be a menace and a danger to the inhabitants of Missouri and St. Louis using the water of the Mississippi River at the intake at the
7704 chain of rocks, for I know of nothing with which the infection contained in such sewage would meet which would be certainly destructive of it, and from my knowledge of conditions at Chicago such sewage must be very largely at times infected with typhoid bacilli.

Taking into consideration all the knowledge I have bearing upon your question, I will state it as my opinion that harmful elements of sewage of Chicago have reached the intake of the St. Louis waterworks at the chain of rocks, and have been the cause of typhoid fever among the persons using the water.

Taking into consideration all the data which you have enumerated in your question, I would state it as my opinion that the flow of sewage from the sanitary or drainage canal through the Illi-
7705 nois River has had a deleterious effect upon the health of the persons living in St. Louis and using the water drawn from the intake at the chain of rocks.

The conditions affecting the purification of streams from the materials introduced by sewage are so complex that in my opinion it would be impossible by the ordinary methods to determine at what points in the river the purification was always effected. The only way which I can suggest as being entirely satisfactory for the solution

of such a problem is the study of the results of the use of such a water by a considerable community. If this fails to show any evidence of the deleterious effects produced by water, and especially if they fail to show any evidence of typhoid fever, I should think that we might reasonably conclude that that point was without the zone of danger, during the time of experiments, but owing to the fact that the chief deleterious constituents of sewage are living organisms, that they may be protected at certain times and in certain numbers by being enveloped in solid materials which would protect them from the influences ordinarily working against them in streams, it would be impossible to predict with certainty that at some other time than the time of experiment the water would be perfectly safe at that point.

It is important to recognize in the question of sewage pollution that the chief injurious ingredients are living organisms, and the question of dilution does not come into the discussion to any
7706 thing like the extent that would be the case if the injurious ingredients were inert chemical substances.

Replying to the question, I would say that I know of no experiments which are entirely satisfactory as proving typhoid bacilli are not able to survive the immersing of sewage for a period of three or four days; that there is nothing in the way of experimental knowledge to show that the typhoid bacillus may not survive in sewage for longer periods, and that taking these facts into consideration, and the further fact that typhoid bacilli might be deposited in the bottom of a stream at any point between the emptying of the drainage canal and the mouth of the Illinois under conditions which would
7708 protect it from such deleterious influences as the sewage exerted upon the bacteria, these experiments which are referred to, especially in the question which you asked, it would be my opinion that typhoid bacilli might survive a very much longer period than three or four days, and even be likely to do so if they were
7708 deposited upon the bottom of the Illinois River.

EXPERIMENT OF JORDAN, ZEIT AND RUSSELL.

In my opinion these experiments do not exemplify the true conditions which exist in the water of the drainage canal with relation to the life of the typhoid bacillus discharged into that as a part of the sewage.

The opinion is based on several points—first, the introduction of typhoid bacilli in an artificial culture sac and protected. This does not simulate the condition which would exist in the case of a typhoid bacillus discharged into the sewage and coming from a patient suffer-

ing from typhoid fever, in which case the organisms might readily be, and frequently are, enclosed in fecal masses.

Further, the condition of the bacilli in this sac is quite different from that which they would be under if they were free in the stream where they would be free to settle, deposited in the sediment they might then become protected from the influence of the sew-
7709 age upon them.

In my opinion the condition of the water would be frequently changed at any one point, owing, as I have stated previously in my testimony, to the changeable condition of the discharge which we find coming from the sewers of Chicago.

The difference in the flow between day and night would make a difference in the competition in the sewage water at any one place, and further, the flow at night is very different in composition from the flow during the day.

If the destructive action which was found in this case be exerted upon the bacillus was due in any way to the concentration of the sewage, the further the bacilli moved down the stream the less they would be subjected to this, because of the increased dilution in the lower stretches of the river.

I know of no previous experiments which were of such a character as to warrant the experimenters in limiting the longevity of the typhoid germ, either in sewage or sewage polluted water, for
7710 less than six days, and I know of no experts as having written any article expressing the opinion that the longevity of typhoid fever germs in sewage or polluted water is within the limit of six days.

As far as I know, this period of time, as limited in this experiment of Prof. Jordan is shorter than given by other authorities; most experiments of this sort have demonstrated that sewage is in concentrated form detrimental to the life of the typhoid bacillus, but the length of time which bacteria have lived in sewage of the different experiments have been so various that I do not recall a limitation expressed by any standard authorities on the subject.

Q. Doctor, I will ask you if you know of any instance where typhoid fever germs are known to have lived in sewage longer than six days?

A. Yes, there are published records of experiments showing a longer period than six days. To refresh my memory a moment, the one set of experiments that I have in mind are those of Dr. Horrock's, who showed that typhoid bacilli survived, notwithstanding sewage, a period of fourteen days, and there have been other experiments made by different experimenters on this point.

As I stated, I do not know of any one who has felt justified as the result of these experiments in limiting the period which ty-
7711 phoid bacilli might survive in sewage when they were introduced in what we might speak of as natural media and under natural conditions.

Taking into consideration the data to which you have called my attention, and considering also the other facts which have come to my attention concerning the probable life of the typhoid bacillus after it has left the body of the patient, I would express it as my opinion that we would not be justified in concluding that the life of the typhoid bacillus would be limited to a period of three or four days under the conditions which are found to prevail; in the drainage canal and the Illinois River. These conclusions would have
7712 to be based, in my opinion, upon the evidence as shown in the chemical results that organic matter was so far decomposed as to admit no nutrient to this bacillus, and that I cannot see any justification for in the results.

As far as the bacterial results go, the deduction would have to be made from the experiments indicating the presence of small quantities of colon bacilli, and the experiments in the sacs relating to the life of the typhoid bacillus under those conditions. In my opinion the experiments in those sacs deviate too far from the condition which exists naturally, and they are so much at variance with the ordinary experience which persons have had who have had to deal with the tracing of epidemics of typhoid fever that they seem to me to afford facts altogether too incomplete to risk an opinion of such wide and far-reaching importance as the disease that
7712-13 would follow in a case of this sort. The disease is too grave to be based upon any such experiments, in my opinion.

Taking into consideration the various data to which you have called my attention, I will state that I have been able to find no evidence which to my mind is conclusive that the agencies in work in the streams are adequate to destroy the typhoid bacillus which undoubtedly is introduced into the sewage of Chicago, and-
7714 through it into the Illinois River, and therefore I believe that dangerous and infectious pollution might reach the intake of the St. Louis waterworks.

In answer to your question, I would state that certain of the data which I have been able to consider as bearing upon this
7715 problem I believe that typhoid bacilli from the sewers of Chicago have reached the intake of the St. Louis waterworks.

I considered the problems involved in your question, and will

state in my opinion that the data available, especially those relating to typhoid fever upon the watersheds of the Mississippi and Missouri rivers above the intake of the St. Louis waterworks and the
7716 data concerning the occurrence of typhoid fever in Chicago Sanitary District, are sufficient to demonstrate that the increase in typhoid fever has been due, in considerable part at least, to infection from the Chicago sewage.

In reply I would state that it is my belief that a comparison of the typhoid fever death rates in the City of St. Louis from 1896 to 1899 and 1900 to 1903, inclusive, is a competent method of deciding whether there has been an increase of typhoid fever in St.
7717 Louis, and further, I would state that in my belief that is the best method of testing the question as to whether there has been a change in the quality of the drinking water supplied to St. Louis with reference to its infection from typhoid fever.

In my opinion there has been an increase in the typhoid death
7718 rate in St. Louis, based upon the mortality for 100,000 population, or upon the per cent of typhoid deaths to the total mortality.

I base this opinion upon the study of the facts presented from compilations as to the death rates made from the records of the mortuary office and a comparison of the rates for the two periods.

I have examined the data given in the Health Commissioner's report and also given in the compilation from the mortuary office referred to, and have confirmed the data, and will state it is my opinion, based upon all these examinations and comparisons, that there has been an increase in the typhoid death rate during the period covered by the four years, 1900 to 1903, inclusive.

I will state that the comparisons which I have just made indicate that the increase has been a very considerable one, and has been more noticeable during the winter and spring months than it
7720 has been during the summer and autumn months.

I think that the use of the Widal test has probably not affected very materially reports of deaths of typhoid fever. Its influence has been more marked in the matter of correct diagnosis of the milder cases of typhoid fever.

Q. Doctor, at what ages do most of the deaths from typhoid fever occur?

A. The ages of most susceptibility from typhoid fever are from 15 to 30, though there are many cases between 10 and 40; the cases under 10 and over 40 being less common than in the other decades.

Q. Is not the disease rare in infants and persons over 60
7722 years of age?

A. Yes, sir, the disease is comparatively rare in those ages.

FILTRATION.

I have had occasion to consider the cost of operating filtration plants, especially as related to the expert oversight of their operation, this having come to my attention through my connection with
7722 several water companies.

Taking into consideration the facts which you have called to my attention, I will state it as my opinion that the installation and operation of a filter plant at St. Louis would be more expensive by reason of the discharge of the sewage of Chicago into the Illinois River, and that if the deleterious agents in this sewage were removed that the cost of the installation and maintenance of a filter plant at St. Louis would be lessened.

CROSS-EXAMINATION,

By Mr. Todd.

I have never made an examination of the whole course of a river as long as the Illinois, but I have made frequent analyses covering several years of the Connecticut River in that part which goes through the State of Connecticut.

I would reply that that is not possible by any kind of analysis,
7723 chemical or bacterial, to arrive at a positive conclusion as to the condition of a river at all times and all seasons.

Q. What do you mean by taking samples proportional to the volume of the river?

A. I mean this, that if a stream is flowing, to assume 1,000 gallons a minute at one point in a small stream, and you take a gallon sample of that stream flowing 2,000 gallons, you ought to take two gallons.

You have to take a sample of the water of the gallon for definite determinations, and that sample has to be taken by a thorough mixing of the samples. As far as the chemical features are concerned they can be diffused equally through the volume, so that a sample of say a half liter will represent a chemical composition of the whole.

Q. Would not the samples bear the same relation to the two gallons as the samples taken out of the river in small quantities would be to the river at the same time and place?

A. Precisely the same proportion, but the results have to be considered in making an average; that is, you would have to give twice the value in making your average on the sample col-
7724 lected when the flow was 2,000 cc. per minute than you would when the flow was 1,000.

I have stated that if you want to get a result from a thorough sampling you will have to take them continuously. There is but one way to do that, and that is to have some sort of a weir arrangement which would give you a continuous flow. There is no way of taking a sample every five minutes or every hour or every week which would fully represent the samples.

Q. In the examination which you made of the Connecticut River, did you pursue there that method?

A. Not by any means. There was no attempt to make a thorough examination of the sanitary condition of the river at all times. I know of no analyst of waters who has pursued such a course in Europe or in this country, and I should say that no one would be likely to recommend such a thing, because the results obtained by those methods would not be comparable to the experience, of course; in other words, a method is required to solve problems.

The ideal method would be that which you have asked for, which, in my opinion, is an ideal method, and which cannot be solved by the limitations of a bacteriologist and chemical analyst which you have asked me to consider. If you wish to sample a stream at any point and get a set of figures which will represent accurately the condition of the stream at that point, you would have to at
7725 every point.

Assuming that you could get an accurate determination, I should say that the nearer the stations were together the more closely you would approximate to that result.

In my investigation of the Connecticut River samples were taken once a month. It was with a view to obtaining the data showing the general character of the water obtained in the river, but it was not with a view of ascertaining the character of the flow at all times and all seasons.

Q. Did you make a bacteriological examination of the waters of this river covering the periods that you made the exami-
7726 nations?

A. No, sir.

Those that I have enumerated I have made frequent determinations, some running over periods of three years, monthly samples, and for the purpose of showing the general chemical character of the

water, but not for the purpose of showing all the details of the sanitary conditions of the river.

In the Connecticut River samples were taken at four stations. The Connecticut River is about 75 miles long.

I should say in this connection that the Connecticut River, Nantucket River and Still River, that I may not be misunderstood
7727 that none of these streams are used for drinking supplies, and the problem was not as to the suitability of the water for drinking.*

Q. Have you had any experience in the operation and management of what is known as septic tanks?

A. No, sir.

Q. Have you studied the septic operation of these tanks personally?

A. Not in the way of making analysis, no.

Q. Have you visited any septic tanks for the purpose of studying their operation?

A. Not any large tanks which were taking the sewage of any considerable community as they are, but of those located in the east. There are one or two places that I have examined. We have one near New Haven which, as it is run, is practically a septic tank, or comes pretty near it in its operation of being a cess-pool.

Q. Do you regard yourself as an expert on septic tanks?

A. I consider that by my study of the subject I understand pretty well the chemical and bacteriological theory of a septic tank, but I should not undertake to agree to discuss the engineering features of the construction of a septic tank. That is not in the scope of my work.

In making the reply to the tables of Prof. Kinnicutt, I referred to what I could do with this data, basing it upon the evidence that I have found in the literature, which goes to show that the knowledge of what destructive action takes place in septic tanks is not yet complete, and in this point I agree thoroughly with the statement made in the testimony of Prof. Kinnicutt when he states that the
7728 experiments on this point are not very numerous.

From the evidence given in the tables I should say that there was a very considerable reduction in the constituents of the sewage beyond the two points named, the mouth of the canal and Lockport, and so testified.

According to the tables, especially table E, there is a loss which

*This witness has made no chemical survey of any river to ascertain its quality as a water-supply.

is to be accounted for by the bacterial action which takes place and is responsible for the beneficial action of the septic tanks.

I am acquainted with the Illinois River by description, its
7730 fall and its banks.

Q. Prior to January, 1900, would you consider the Missouri as a safe water for domestic and drinking purposes in its raw state?

A. In its raw state I would not recommend the stream re-
7732 ferred to for drinking water in any community.

Q. Would you recommend the Missouri River as treated by the settling basins in St. Louis as a safe drinking water for drinking and domestic purposes before the opening of the drainage canal?

A. In answering that question I must assume that the water treated in the sedimentation tanks for the water supply of St. Louis is the Missouri River water. Under this understanding, I would say that my recommendation would have to include two considerations. If it were feasible to recommend an ideal water supply, under all circumstances, I should recommend that the water of the Missouri River be treated more efficiently than by the sedimentation tanks, but I should also have to consider that the statistics of the typhoid fever rate which, in my opinion, is on the whole the best test of the sanitary condition of the drinking water during the four years, 1896 to 1899, inclusive, would indicate that the water at that time was in a pretty satisfactory condition, and it was not possible to have the ideal condition, I would be willing to recommend under those conditions, the continued careful use of the present sedimentation system.

Q. Would you recommend that river water for drinking and domestic purposes that as a population upon the watershed such as the Missouri River has, which is only treated with settling basins, when the water does not remain in a quiescent state to exceed three days, for drinking and domestic purposes?

A. In reply to your question I should have to refer you to my answer to your previous question as to the recommendations of the Missouri River water, and would state again that if it were
7735 feasible to obtain an ideal water-supply I should recommend the installation of much more efficient purifying apparatus, but in view of the typhoid statistics I might recommend a continuance of the present system under careful oversight.

Replying to your question whether you assume the distance in time flow from Kansas City and St. Charles and the number of deaths in the Missouri River, etc., I would again refer you to my answer on the original question as to recommending the water of the Missouri River. * * * But I would again state that the typhoid statistics

during this period compare so favorably with those of other
7736 cities having reasonably good water supplies that I might recommend a continued use of the water, even in view of the facts which you have presented to me.

Replying to your question, I will say that I do not consider such a water as absolutely safe water, and that there are very few absolutely safe waters, even waters which have had a certain amount of contamination, and are filtered, are not absolutely safe. One
7737 has to decide as to the reasonable safety of all conditions, and this I consider has been shown during the years in question by the statistics which have been quoted.

In reply to your question, I would refer you to my statement that I would recommend the water as a reasonably safe water; that personally knowing the danger of typhoid infection, and having in my family young persons of the age which is particularly susceptible to the infection of typhoid fever, I should hesitate myself to use it and to have my family use it, and would not do so under ordinary conditions, but I should have to recognize and did recognize
7738 in giving the opinion that I could recommend the water as a reasonably safe water, for the average communities in the United States do not as yet require as high a standard for drinking water as I should with my own knowledge for my own individual use.

Assuming that I was forced to express an opinion as to whether the water was absolutely safe, and that I was not permitted and not desired to recommend anything but an absolutely safe water, I would not recommend this water as an absolutely safe water.

The Mississippi River water above Grafton is to be judged by
7739 the same test as applied to the Missouri River.

Q. Have you ever been called upon to pass judgment upon the quality of a river for drinking and domestic purposes when you recommended subsidence?

A. No, sir.

Q. Have you ever been called upon to pass judgment upon the quality of a river water in its raw state for any municipalities in this country?

A. I have had occasion to give advice on such matters.

Q. Have you ever recommended for municipalities the use of river water without filtering?

A. No, sir.

Q. Have you ever installed a filter plant?

A. No, sir. That does not come within the line of chemistry or bacteriology. I have never operated a filtration plant in the sense

of having charge of the works. I have, of course, made analysis showing the character of the work. I have had nothing to do with the engineering features of a filtration plant. I have never accepted bids for the installation of a filter plant, nor passed upon the reasonableness of the bids. I have never employed men to operate a filter plant or passed upon the reasonableness of their compensation.

Q. Are ou acquainted with what it would cost to operate a filtration plant filtering 200,000,000 gallons of water per day?

A. In a general way I know the cost of filtering water, but it differs under different conditions, and as I give little or not attention to the engineering side I have not paid special attention to them.

I have had no experience in connection with filtration plants in the Mississippi Valley. In a general way I am acquainted with
7744 the number of men necessary to operate a filtration plant, but that is not based upon actual experience. That has to do with the administration and engineering features, of which I have had no experience.

The chief sanitary object of filtering water is to remove the infection.

The question relating to the rapidity of filtration, the character of the filtration, the scientific oversight of the operation of the filter, all depends upon the relative contamination of the water which is to be filtered. * * *

As filters are liable to fail in the operation at times, a filter which is filtering water highly contaminated must have more careful scientific oversight in the way of the testings of the water to get at the general character of the water.

Q. Is it not a fact that the chief cost in the establishment and operation of a filter depends upon the matter in suspension and the question of infection is a matter of secondary consideration.

7745 A. Not from a sanitary standpoint, no, sir.

Q. Have you ever given the question consideration as to the difference between a water that is sewage polluted, greatly charged with matters in suspension, and a water of equal pollution that has infection presented as to difference in cost of operation and maintenance of a filtration?

A. As stated, those are matters which pertain to the engineering side of the problem, and I have not given the details of such matter attention.

Q. Then, Doctor, how are you able, in your examination, to pass an opinion as to the relative cost of filtration here in St. Louis with the waters of the drainage canal turned in over conditions that obtain if the sewage of Chicago was contaminated?

A. The opinion that I expressed regarding that was a general one in regard to the relation and not a specific one, which would require the knowledge of an engineer, and was based upon the considerations which I enumerated a short time ago relating to the question of rapidity of flow through the filters as affecting their size, and the oversight as affecting the character of the effect from a sanitary standpoint, and I do not mean to express it on any other facts.

Q. The opinion, then, was very general?

7746 A. It was general that it would cost more on these accounts.

Q. Doctor, have you made any experiments yourself upon the longevity of the typhoid bacillus?

A. No, sir, not laboratory experiments.

Q. Have you made any experiments under natural conditions of the typhoid bacillus to ascertain its longevity?

A. Those would be what I would call laboratory experiments; I have not. I do not mean to say that it is in connection with laboratory methods. What I meant to say was that I do not know

7747 of anyone who would express an opinion to that effect as to the longevity of the typhoid bacteria under natural conditions of sewage polluted streams.

I have not made any laboratory experiments myself upon the typhoid bacillus in sewage.

Q. Do you know of any experiments that have been made by any bacteriologist in this country or in Europe that simulates natural conditions as nearly as the experiments made by Profs. Jordan, Zeit and Russell, to which you referred, and which were as extensive in their scope as that experiment upon the longevity of the typhoid bacillus?

A. No, sir, I do not.

Q. Can you suggest any experiment that is possible to be made by a bacteriologist that would simulate natural conditions more closely than the experiment made by Profs. Jordan, Russell and Zeit on the longevity of the typhoid germ?

A. Yes, sir. Unquestionably the technique of such experiment could be rendered somewhat more approaching natural conditions, but the problem is so different, the variations in the conditions are so extreme, the conditions that the typhoid bacilli exist in the sewage are so different, that I cannot conceive how laboratory conditions or methods can afford a perfectly satisfactory solution as to the

7749 matter of how long the typhoid bacillus may exist in a stream, and, in my opinion, such data cannot be expected to yield a definite positive answer to that question under any given set of conditions.

Q. Will you state to what technique you refer that could supplement the technique that was employed in the making of this experiment?

A. It would have obviated one difficulty if the sacs had been allowed to float down the stream properly protected, so that they would not have been subjected in succession to a series of different character of water, as they must have been when they were put stationary at one point. These experiments might have been tried in sacs of such sizes as to admit the accumulation of considerable quantities of sediment with a view of ascertaining whether they would have influenced the result. That would have more nearly simulated the conditions in the stream.

Q. What criticism have you to make of the celloidin sac method that was employed by Prof. Zeit?

A. There is no particular criticism that occurs to my mind as comparing the use of the celloidin and the parchment. Of course there was a difference in the fact that one permits dialysis, while the celloidin does not. The experiments were very carefully worked out, and unquestionably they were very well done, but the difficulty of simulating natural conditions are what appeared to me to be of importance.

7750

Q. Do doctors confound typhoid fever with other diseases?

7751 A. Yes, sir.

Q. Under the heading of intermittent, remittent, typho-malaria, congestive and simple continued fevers, what is your opinion as to whether any of these fevers should be properly classified as typhoid fever?

A. It is not uncommon to find a difference in diagnosis in the early stages of typhoid fever and in mild cases between the malarial condition and the typhoid condition, so that I think that errors of this sort are more or less common in the diagnosis of cases, but in the matter of deaths I can see no reason why there should be very much confusion, for the reason, which I have already stated, that by the time a typhoid case reaches the condition where it proves fatal the disease has generally directed itself so as to admit of the application of the diagnosis if there was error. There are doubtless some cases which are never correctly diagnosed.

7752

Q. Did you allow any of the deaths reported under this miscellaneous class as typhoid in arriving at your conclusions as to the typhoid conditions in St. Louis?

A. I have considered, as stated, that possibly, and I have seen, including them all in the typhoid deaths, there is still an increase of

typhoid fever between the two periods, but I have further considered the compilations of the deaths under each of the miscellaneous class, especially with a view of attempting to form an opinion as to whether any considerable portion of them might have been typhoid deaths. I cannot state, of course, that none of them were, and I cannot state personally how many of them were, but considering them from a standpoint of the age of the persons and from the distribution of the cases of death by month it will be seen that there would be comparatively few of those which are classified under this group which should be included in the typhoid class.

The introduction into the city of a considerable number of persons from other sections might have had some effect in raising the number of cases of typhoid fever. The number of cases which come from local infection, such as wells, is indicated to probably not much more have existed during the period since the opening of the canal than they obtained before the opening of the canal. There is, of course, no way in which I can estimate absolutely the proportions of the deaths which occurred during the years 1896 to 1899, inclusive. There is no way in which I could tell the proportion or portion from local causes and those which may be due to some other cause, but the rate which prevailed here during that time was about the same rate which we found in some other better class of cities in this country.

JOHN W. ALVORD.

DIRECT EXAMINATION.

By Mr. Jeffries.

7761 I am a sanitary and hydraulic engineer; have been in the business about twenty-four years. I have been engaged in various capacities with about thirty-five city waterworks plants and about forty-five municipal sewer systems, etc.

I have given the subject of bacteriology and chemistry attention to a limited extent. I have endeavored to keep informed on the subjects which would be of interest to my work as a sanitary engineer. I was employed in 1902 by the special commission that

7763 investigated the extension of the water supply of St. Louis.

I have to some extent made a special study of the typhoid conditions on the water shed above St. Louis; the data was secured from the evidence in this case.

I have prepared a diagram showing the relation of typhoid fever

deaths in St. Louis with typhoid deaths on the water shed.

7766 Diagram.

Introduction of the diagram objected to as not rebuttal.

"It has been the endeavor in this diagram to disclose the cause for the increase in typhoid deaths in St. Louis during the last few years. * * * It will be seen that the deaths from typhoid on the Illinois water shed exclusive of the Sanitary District of Chicago are fairly uniform up to the year 1899, and show a rise in the year 1900, the year in which the drainage canal was opened. Otherwise they seem to be fairly uniform for the years preceding and following the commencement of the rise in the number of typhoid deaths in St. Louis. The deaths on the Missouri River water shed appear also to be reasonably uniform for the period under consideration, and the typhoid deaths on the Mississippi River water shed, while fluctuating somewhat more than the first two described, nevertheless are generally uniform before and near the rise in the typhoid deaths in St. Louis.

In summing up the total typhoid deaths on the water shed above St. Louis, as given in the record, it would appear that while there is some fluctuation and a low period about the year 1896, that at no time since the rise in typhoid deaths in St. Louis have they materially exceeded a fair average rate, and have in fact fallen off since the year 1900. It will be observed, however, that the addition of the deaths from the sanitary district almost doubles the total typhoid

deaths, influencing the pollution of the St. Louis water supply.

7769 and that such addition has materially increased during the years 1901 and 1902, so that in 1902 the total typhoid deaths are nearly two and one-half times the deaths on the water shed above St. Louis, exclusive of the Sanitary District of Chicago.

I am acquainted with the physical condition upon the Illinois, Mississippi and Missouri water sheds, and I should consider after a study of the data that in all human probability the rise in typhoid deaths in the City of St. Louis in the last few years has been caused by the added typhoid contamination from the Sanitary District of Chicago.

7770 (Objected to as not rebuttal.)

The longevity and vitality of the typhoid organism is of special interest to me in my profession in advising municipalities as to the purity and safety of their source of water supply. I have for some years past considered the life of typhoid bacilli would be from sixty to ninety days under favorable environment, and while large masses of such bacilli might be removed from any given source of supply in

a comparatively short time under favorable environments it would not be safe to assume that the water unless thus polluted would be safe to recommend for public use under the time given unless the contamination were eliminated by carefully designed and properly operated system of purification.

7771 I am acquainted with the experiments of Hiram T. Mills. And also the experiments made by Dr. Horrocks, which appear to be similar to those carried out by Mr. Mills.

I am acquainted with the sewerage system of Chicago, and portions of it have been constructed under my design and supervision. The sewerage system of Chicago has very flat gradiants, and requires frequent artificial flushing. It has been the history of heavy rainfalls that the entire contents of the sewers are discarded into the river, bringing into it amount of pollution which has been accumulating for months together. Before the opening of the drainage canal such periods were extremely dangerous to the water supply of the city.

In my opinion the flushing of the sewers of Chicago furnishes conditions more favorable to the longevity of pathogenic bacteria than those under which the experimental work of Mr. Mills and Mr. Horrocks were taken. The discharge of various amounts of pollution at times of flood water appears to furnish the necessary velocity for rapid conveyance through the drainage canal down the Desplaines and Illinois rivers to the intake of the St. Louis water supply. The increment of tributary streams also increases the dilution and decreases the chance of toxic destruction of the total number of typhoid germs present.

My answer refers entirely to ordinary conditions, such as occur perhaps eight or ten times or more in the spring of each year, rather than to exceptional floods. Such floods would naturally produce the danger from typhoid pollution to greater distances from the source or origin.

In case of a heavy rainfall on the water shed of the Chicago River, in order to prevent outflow into Lake Michigan, it is necessary to lower the Bear Trap Dam at Lockport, so as to produce

7773 greater velocity at all stations down the channel at such times. This, undoubtedly, aids the rapidity with which pollution is conveyed from Chicago down the channel to the Desplaines and Illinois rivers.

Below the outlet of the drainage canal at Lockport the Desplaines flows very rapidly to dam number 1. This descent produces rapid velocity. A rainfall will doube the velocity in the channel of from forty to sixty miles per day.

7774 I have read the testimony of Mr. Randolph. The effect of 250,000 cubic feet of water per minute at Bear Trap Dam is to greatly increase the current of the Desplaines and Illinois rivers, and to carry dangerous pollution a greater distance and with more rapidity. I am unable to find anything in Mr. Randolph's testimony which gives any clue to the amount of discharge in the Desplaines and Illinois rivers at Joliet or Peoria, and, therefore, am unable to determine what stage the river was in at the time of his float experiments.

7775 I only find a statement that a float passed over this distance in fifteen days, which is raised to eighteen and one-half days by dividing by 8/10. The use of the decimal .8 in Mr. Randolph's testimony is a very rough approximation. I do not consider the floats used by Mr. Randolph as surface floats, but believe that they give the mean velocity of the central portions of the stream with a fair degree of accuracy. I believe the corrections made by Mr. Randolph are not necessary. I believe that fifteen days' actual time would fairly represent the ability of the waters of the Desplaines and Illinois rivers to carry pollution to the chain of rocks at

7776 the stage when the experiments were made.

I should judge that the float experiments of Mr. Randolph were taken at a much lower stage of the river than were those of Prof. Van Ornum, * * * from Bridgeport to the Chain

7777 of Rocks I find that 9.8 days are consumed, using mean velocity to Joliet, and Prof. Van Ornum's float experiment from there to the Chain of Rocks. I do not consider that this is the shortest time in which pollution will travel this distance, but believe that a maximum flood, such as occurred in 1892, would reduce this time to at least eight days, and possibly slightly less. The 9.8 days represents, to my mind, a stage which could be counted upon as occurring a number of times in each year. Not having been able to ascertain the specific stage at the time of Mr. Randolph's experiment, I should not be able to state positively that his experiments were made at the maximum stage of the river, but speaking gen-

7779 erally, it is my impression that it was, and represents the average of the minimum velocity of the ordinary dry seasons of the year between the Chicago River and the Chain of Rocks.

7780 I have examined Mr. Rudolph Hering's charts offered in evidence, and have prepared a chart of a similar kind on the Illinois River.

7782 Alvord's chart.

7783 Explanation of the chart.

This chart represents the comparative pollution contributed

by the fatal cases alone. I find that whereas Hering's diagram shows that the typhoid pollution entering the intake is equivalent at the end of eighteen and one-half days to an infection from tribu-
7785 tary population immediately above a city of 13,000 people, the conclusion of the diagram would seem to indicate that a normal flow of fifteen days would be equivalent to an infection from the tributary population with a death rate of 20 per 100,000 living on the city located immediately above the intake with a population of about 90,000 people, put on the basis of spring floods such as were gauged by Prof. Van Ornum, the infection would be equivalent to the population of a city of 415,000. With a maximum flood,
7786 it would be equivalent to a population of 960,000, with a typhoid death rate of 20 per 100,000.

The experiments upon which the charts are based I might term incomplete investigations. The results show the typhoid germs do live under the conditions of the experiment the length of time given, but they do not show that typhoid germs can live much longer.

I have given particular attention to the development of septic
7788 tanks, and have designed some ten or fifteen for municipalities. Flowing sewage ordinarily does not undergo septic action. Diluted sewage flowing in an open channel does not simulate septic tank conditions.

Q. State whether or not septic action to a considerable extent takes place in the sewage of Chicago during its passage to the drainage canal.

A. It does not. The chemical data introduced by the defendants in regard to the character of the contents of the Chicago drainage canal, in my opinion, does not indicate that septic action has taken place therein. The improvement in the sewage, as found by Prof. Kinnicutt, would seem to me to be largely due to aerobic action, possibly there is an aerobic action to a very limited extent, but not enough, in my opinion, to influence the results perceptibly.

The dilution of the sewage with Lake Michigan water is not a
7789 useful preliminary to septic action. I believe typhoid germs could survive materially longer under the present conditions than was the case formerly in the Illinois and Michigan canal
7790 in the south branch of the Chicago River.

The presence of Chicago sewage in the waters of the Illinois, in my opinion, makes it more costly to provide suitable water for domestic purposes for the City of St. Louis.

The design and construction of a filtration plant dealing with a seriously polluted water, especially with one of known high typhoid

pollution, should be more complete and delicately adjusted to
7791 its work than one dealing with water of rare infection and presenting less dangerous difficulties, such as turbidity and color.

The added protection could take the form either of double filtration or have complete sedimentation in more than one stage followed by most careful filtration. Double filtration would be more costly than single filtration. It is my opinion that they would greatly increase the cost of filtration, both in its first construction and in operation. Single sand filtration, as practiced in the United States, is not always a protection from the danger of typhoid infec-
7792 tion.

Single sand filters have failed in my observation to properly
7793 protect water supplies of Rock Island, Butler, Pennsylvania, Beaver Falls, etc.

I am of the opinion that it is entirely practicable to retain the Drainage Canal so that it can be still employed for keeping the Chicago River water in condition, and yet avoid pouring unpurified sewage into and through the canal and into the DesPlaines and Illinois rivers, and I would suggest as the proper remedy, the construction of suitable intercepting sewers along the Chicago River and its branches by means of which the sewage flow of the city may be kept out of the Chicago River and lead along its banks to the upper end of the Drainage Canal, beyond Bridgeport, and then raised by a suitable pumping station, preferably operated with water power derived from the Drainage Canal to and into a suitable purification plant constructed in accordance with the latest bacteriological principles, and effectually remove from such sewage all or practically all of its organic waste and pathogenic bacteria, and emptying the effluent from such sewage plant into the Drainage Canal near Bridgeport, to be conveyed through the same and through the DesPlaines and Illinois rivers in a harmless and purified state.

I have considered the expense in a general way and am of the opinion that such intercepting sewers and purification plant could be constructed at an expense no greater than that necessary to widen the south branch of the Chicago River in order to increase its flow of dilution water to the requirements of dilution. And I am further of the opinion that the operating expense of such a plant would be no greater than the operating expense of the present system of pumping sewage and the necessary dilution water through the same for
7795 the northerly and southerly portions of the Sanitary District, and the dilution water for the proposed additions to such Sanitary District.

CROSS-EXAMINATION.

By Mr. Todd.

I estimate in dollars and cents that the cost of such a plant would be between twelve and fifteen millions of dollars, and it contemplates the purification of the entire sewage of the Sanitary District.

I should think it necessary to build intercepting sewers on each side of the river along the most economical location, connecting it with the mouth of the sewers on each side of the river, either by short branch tunnels, grouping several sewers together on the opposite side, or, in the case of large sewers, by direct tunnel connections in each case. I would not be able to give you those detail figures at this time, because I have not them with me. The number of acres necessary at Bridgeport would depend entirely upon which of the several available systems of bacterial purification might be adopted. I do not think that I had any particular one in mind. My estimate is made
7797 by estimating the cost of the one which in all probability would be the least and most expensive. It would require about 1,000 acres of land, which could be bought for about half a million dollars.

Q. Have you any spot in mind where such an amount of land could be had near Bridgeport at $500 per acre?

A. The Sanitary District of Chicago has a large amount of land in that vicinity, and, without having given the subject particular attention, I should judge that it might be possible that they had lands enough without having to purchase any additional. I would not limit myself to lands three or four miles from Bridgeport. The plant could be eight or ten miles away.

In bringing the sewage from different sections of the city I
7798 placed about $5,000,000 upon the cost of the additional sewers in order to bring the sewage to the plant.

Q. Will you give in detail, professor, the plan which you have in mind for the disposal of Chicago sewage?

A. Well, I have quite a number of plans in mind. I have not
7799 limited myself to any one plan.

Q. What experiments have you conducted upon the longevity of the typhoid germ, as a bacteriologist?

A. None whatever.

Q. Have you ever separated the typhoid germ in the laboratory from the excreta of typhoid patients?

A. I have not.

Q. Are you sufficient of a bacteriologist to do so?

A. I am not.

Q. Have you ever made any experiments of your own upon the longevity of the typhoid germ in sewage?

A. I have not.

Q. Have you made any experiments of your own upon the longevity of the typhoid germ in sterilized water, in lake water, in water of the Drainage Canal, or in the water of the Illinois River?

A. I have not.

7802 Q. How do the methods employed by Mr. Hiram T. Mills compare with the methods employed by Professors Jordan, Zeit and Russell, in the detection of the typhoid germ?

A. I should not consider myself competent to criticize the technique of either Mr. Mills or Messrs. Jordan, Zeit and and Russell.

Q. In the chart which you have introduced in evidence in which you have testified that since the opening of the Drainage Canal the typhoid rate in the cities on the water shed of the Illinois River has gone up since 1899 and 1900, exclusive of Chicago, I believe you called special attention to that feature of the chart in your direct testimony, did you?

A. It seemed to me a variation in the general result worth noticing.

Q. How do you account for that rise as evidenced on that chart from 1899 to 1900?

A. I have not attempted to account for it, particularly.

Q. For the years 1900-1-2 there is a fall in the typhoid along the Illinois River, exclusive of Chicago, is there not, as evidenced by the chart?

A. There is a slight fall.

Q. How do you account for that?

A. I have not attempted to account for it.

Q. Upon the Mississippi River there is a rise for the typhoid rate as evidenced by the chart; how do you account for that?

A. I have not attempted to account for that or for any of the minor fluctuations except on the theory that there are always

7803 fluctuations in any such death rate, and that in order to be of interest they would be somewhat marked.

Q. Is there anything on this chart that shows that the rise of typhoid fever in the City of St. Louis is due to the typhoid conditions in the City of Chicago?

A. I think there is.

Q. Will you point out on this chart where such a fact appears?

A. The diagram shows that the deaths on each of the three water sheds contributing to St. Louis are fairly and reasonably uniform, bar-

ring the local fluctuations which always occur in such death rates from various slight causes, but the diagram probably shows that at and from the year 1900 a very large number of deaths were added to the normal deaths upon the combined water sheds by the opening of the Drainage Canal. In two years after the opening of the Drainage Canal the total number of deaths attributable to the water supply of St. Louis has been more than doubled; in marked contrast
7804 to the fairly uniform conditions which preaviled on each water shed, excluding the Sanitary District of Chicago.

Q. Have you compared the typhoid conditions in the City of Chicago by the months with the typhoid conditions in the City of St. Louis by the months?

A. I have not.

Q. Would such a comparison, allowing thirty days' interval between Chicago and St. Louis to intervene, shed any light on the question as to whether Chicago has any effect upon the typhoid conditions in St. Louis, in your opinion?

A. I should be afraid that it would induce too many fluctuations and variables of the greatest value. I should prefer to take the average for the year, showing in a marked manner any main distinguishing characteristics.

An increase of typhoid fever in the City of St. Charles might be expressed in the typhoid conditions in the City of St. Louis.

Q. Might not an increase of typhoid fever in Kansas City be expressed in the increase in the City of St. Louis, taking into consideration that 67 per cent. of the water consumed in St. Louis is Missouri River water?

A. It might be possible, but, as far as I have been able to observe, it is not.

Q. Can you tell whether the infection that afflicted St. Louis comes from St. Paul, Minneapolis and the cities on the Mississippi River, the cities on the Missouri River or the cities on the Illinois River?

7805 A. I think, when conditions are marked and data fairly adequate, that it is possible to tell.

Q. Do you consider that any of the typhoid fever cases in the City of St. Louis are due to the Missouri River water?

A. There is always that possibility. My opinion would be that the percentage of the normal deaths in St. Louis prior to 1900 would very probably be due to the contamination from water of the Missouri River.

Q. Would you regard the conditions at St. Charles as contrib-

unting as much typhoid as the City of Kansas City to the City of St. Louis?

A. It is probable that it may have an equal effect upon the normal typhoid deaths in St. Louis.

Q. If one typhoid fever patient could create the epidemic at Plymouth, Massachusetts, what effect, in your opinion, would the number of cases of typhoid fever in the City of St. Charles, as evidenced by the statistics which you have studied, have upon the water supply of St. Louis?

A. There are always possibilities of contamination from unexpected sources. I should be inclined to think from my diagram
7806 that the typhoid deaths in St. Charles might have influenced the normal deaths in St. Louis prior to 1900 to some unknown percentage. I should be disinclined to think that since 1900 the typhoid in St. Charles could have been responsible for so marked a change in the number of deaths in St. Louis from typhoid.

Q. Does the number of people afflicted with typhoid fever in a given city depend upon the number of people that have typhoid fever above on the water shed?

A. It does to some extent when you are considering averages over long periods.

Q. How do you account for the Plymouth epidemic that was due to one typhoid fever case?

A. There are always exceptional occurrences of that kind.

Q. Might not such an exceptional occurrence happen between St. Charles and the City of St. Louis?

A. It is within the range of possibility. In the absence of direct proof that the typhoid deaths in St. Charles have been responsible for the rise in deaths in St. Louis, we are obliged to proceed on the theory of probability, and the theory of probability would indicate that the preponderating number of deaths, wherever they may be found, are the responsible cause. Therefore, I would be disinclined to attribute, in the absence of direct proof, the rise in the typhoid deaths in St. Louis to the rise in St. Charles.

Q. Do you employ the theory of probability in drawing your conclusions that the typhoid increase in St. Louis is due to Chicago?

A. Whenever we deal with a problem of the magnitude of this
7807 problem and its complications, we are obliged, as one of the controlling data, to proceed on such theory.

Q. And that theory has been employed by you in giving your opinion on the effect of the opening of the canal upon the typhoid conditions in St. Louis?

A. As one of the data from which I draw my conclusions, I should attach this importance to the typhoid conditions on the Missouri River, that I observe that the typhoid deaths on the Missouri River, all things considered, have been fairly uniform for the whole period shown, and, therefore, whatever percentage the contributory infection of the Missouri River water shed may have produced prior to 1900, I should be inclined to attribute an equal degree to the period since 1900. I do not regard the water of the Missouri River
7808 as a safe drinking water. The water of the Missouri River has been constantly deteriorating, and the same is probably true of all of our Western rivers.

I do not regard the water of the Mississippi River at St. Louis, exclusive of the Sanitary District, as an entirely safe drinking water, and I should not like to so recommend it.

I do not know what the discharges of the Illinois River were at the time Mr. Randolph made his experiment.

Q. If you do not know the stages of the river and its flow, how are you able to give that opinion?

7809 A. I do not think that that opinion is as valuable as it would be if I did know the exact stages of the flow. It is an intelligent guess.

Q. When you corrected Professor Van Ornum's time what method did you employ in doing it?

7810 A. I calculated the mean velocity by the cross-section and fall and deducted the surface velocity by dividing it by .8

Q. Dilution minimizes danger from infection, does it not?

A. Not altogether. It increases the longevity of the typhoid germ.

Q. But it disseminates in a greater body of water, thereby diminishing, on the theory of probability, the danger from infection, does it not?

A. I should think that would be a fair statement; yes, sir.

Q. By the method that you employed on the Illinois end of this chart, applying that same method to the Missouri and the Mississippi rivers, will you state what the results show?

A. I have not undertaken to reduce the Missouri and Mississippi rivers to terms of typhoid pollution at St. Louis in the manner shown by Mr. Hering.

Q. Why?

A. Because I did not deem them pertinent to this inquiry.

Q. In order to make a comparison between your method of calculation and the method employed by Mr. Hering, you do not think it

would have been more accurate to have carried out your charts
7812 for the three rivers instead of one?

A. I do not see how it could.

Q. Do you not understand Mr. Hering's chart to be for the purpose of showing the relative pollution of the three rivers with a ratio of 13 to 97 and 106, whether expressed in people or otherwise?

A. I understand that that was one of the facts which he endeavored to bring out, but I also understood from the study of his chart that he was endeavoring to bring out as well the probable amount of pollution which would reach the intake at the Chain of Rocks from the Sanitary District of Chicago, based upon the experiments of Mr. Hiram T. Mills and the float experiments of Mr. Randolph.

Q. You did not understand his testimony and the chart to mean that there was a city of 13,000 people dumping sewage into the
7813 Mississippi River at the intake?

A. I took it that that was the practical effect of his reasoning. In the construction of a filter for a water comparatively clear, but subject to typhoid infection, the infection will, undoubtedly, be the greatest cause of expense. It would cost more to filter the Missouri River, based on turpidity, but based on typhoid infection, the Illinois River would cost more.

At Grafton I should say the entire infection would be at
7814 least equal in cost to the turbidity. For the Mississippi River I should think the cost would be about equal for both turbidity and infection.

I should say that it would cost more to filter the Illinois River at Grafton, for the reason that in filtering the Illinois River at Grafton we are obliged at first to provide for the cost of removing the turbidity, which, while it is less than the turbidity of the Mississippi, and in addition to this question to provide for the cost of protection
7815 against typhoid pollution, which, in my opinion, would be greater than in the case of the Mississippi River.

If John W. Hill should testify that infection was no element of cost in the operation and installation of the plant at Philadelphia, I think I should be disinclined to agree with him.

Q. Has the consideration of infection added to the cost of any plant which you have been connected with?

A. Yes. At the plant where I considered sewage purification. That plant was situated at Lake Forest, a suburb north of Chicago. The plant for the filtration of the water cost from seven to eight thousand dollars. Lake Forest has a population of 2,000.

Q. Have you designed any filter plant for any city in the country larger than Lake Forest?

7817 A. Yes; I designed a plant last summer for Ottumwa, Iowa. It has not been installed yet, and they have as yet not been accepted, and I think the chances are against it.

Q. Then, the only personal practical experience that you have had in connection with the building of filtration plants is limited to Lake Forest?

A. No, sir. I have been engaged upon a plant at Terre Haute, Indiana, quite a large plant.

Q. A filtration plant?

A. Yes, sir. I was in copartnership with the responsible engineer in charge and superintended it.

Q. Did you design that filtration plant?

A. No, sir. I had the experience of being connected with its construction. It was a mechanical filter plant, however, and mechanical filter plants are really largely designed by the mechanical filter companies.

Q. Then, in your experience in the installation of this patent filter and building the filter at Lake Forest, does that include all your personal connection with the construction of filters?

A. My personal connection with the design and construction of filter plants has been rather more limited than my experience in the design and construction of sewage plants; at the same time, I have designed a number of important plants for the purification of water supplies, and constructed others, and had to do with the operation of still others, perhaps to the total number of eight or ten altogether.

Q. But in the active construction and building of filter plants, where you have figured on cost and were responsible for the

7818 filters, are these the only two plants that you have been connected with in that way?

A. I believe they are.

7821 E. E. LOCHRIDGE.

DIRECT EXAMINATION.

By Mr. Jeffries.

Qualifications.

Q. I request you to state whether or not the number of typhoid fever deaths given upon that table for the years 1896 to 1902, inclusive, is approximately correct?

A. It varies only slightly from the results obtained by compiling the tables attributable to typhoid fever in the record books of the mortuary office.

Q. Will you state whether or not, in your opinion, any comparison of the typhoid fever deaths previous to 1896 with those subsequent to 1896 would be practicable as a means of determining whether or not typhoid fever had or had not increased in St. Louis after the opening of the Chicago Drainage Canal, on January 17, 1900?

(Objected to for the reason it is not rebuttal.)

A. I do not believe any such comparison is either practicable or feasible, for the reason that, while previous to 1896 the intake was so located as to expose the water supply to infection from sewers coming from the city, and during 1894 and 1895 the intake was removed to the Chain of Rocks. In order to show the great change in the typhoid fever mortality of the City of St. Louis at the time the intake was moved, I have prepared a diagram which serves to illustrate this point, as well as certain other points, to which I have occasion to refer hereafter.

7825 Move to strike out answer.

Chart showing thirty years of typhoid fever.

This chart represents the per cent. of deaths from typhoid fever and the total mortality of the city as taken from the Board of Health records of the Health Department. It will be noted that the death rate was uniformly high up to the time of the change of the intake from Bissell's Point to the Chain of Rocks; following this change there is a period of five years in which the mortality is much lower. In 1900 there is a considerable increase, and a step-like increase through the subsequent years.*

Q. Have you examined the records of the deaths from other fevers in the mortuary office of the Health Department of the City of St. Louis, remittent, intermittent, typho-malaria, congestive and simple continued fevers, for the four years preceding and the four years following the opening of the Chicago Drainage Canal?

A. I have.

Q. Please state what you found upon your examination of the mortuary records respecting the deaths from typhoid fever and remittent, intermittent, typho-malaria, congestive and simple continued fever?

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*All questions propounded to and answers given by this witness were objected to and moved, on part of defendants, to be stricken out as not rebuttal and incompetent.

A. I have examined these records and have made tables showing the number of deaths from the causes mentioned in the question in each month of the year from 1896 to 1903, inclusive, which tables are as follows:

7828 Chart No. 4, typhoid fever deaths.
7829 Chart No. 5, remittent fever deaths.
7830 Chart No. 6, intermittent fever deaths.
7831 Chart No. 7, typho-malaria fever deaths.
7832 Chart No. 8, congestive fever deaths.
7833 Chart No. 9, continued fever deaths.

Q. State whether or not in your examination of the mortuary records in the office of the Board of Health for the City of St. Louis you discovered during your examination any tables designated as deaths due to simple continued fevers during those years?

A. I find these deaths marked continued or continuing fevers, but none marked simple continued fever in the years 1896 to 1903, inclusive.

Q. State whether or not you made any examination of the deaths reported from malarial fever during the years 1896 to 1903, inclusive, as malarial fever, and as shown in the original records of the mortuary office of the Health Department of the City of St. Louis?

A. I have made a table of the deaths which I found recorded
1835 in the records of the mortuary office in the City of St. Louis from malarial fever for the years from 1896 to 1903, by months, is as follows:

Chart No. 10, malarial fever deaths.

Adding together the deaths which I found in a study of the records at the mortuary office from remittent, intermittent, typho-malaria, congestive and continued fevers, I find that for the years 1896 to 1899, inclusive, there were, respectively, 129, 105, 85 and 86 deaths, and that if the number of deaths which I found in the records of the mortuary office for malarial fever are added to those, there are in these years, respectively, 156, 140, 108 and 121 deaths, while Professor Jordan gave for the corresponding years 177, 172, 134 and 148. The number of deaths which I find recorded on the books in the mortuary office from these causes is a little lower in each year than the list taken by Professor Jordan from the printed health reports. In the four years from 1900 to 1903, inclusive, adding together the deaths which I found in the books of the mortuary office of the City of St. Louis from intermittent, remittent, typho-malaria, congestive

and simple continued fevers, I find for these years 77, 62, 76
7837 and 73. Adding to these the deaths which I find of malarial fever for these years, there were 137, 90, 114 and 126, or a
7838 little higher in each year than those given by Professor Jordan.

Considering the fact that the malarial fever deaths were IN ALL PROBABILITY recorded in this list, as they do not occur under any other caption, so far as could be discovered, in the printed health reports, I find that Professor Jordan has in his list 21 more deaths in 1896, 32 in 1897, 26 more in 1898 and 26 more in 1899;
7838 25 less in 1900, 10 in 1901, 12 in 1902 and 35 in 1903 than I found in my study of the records in the mortuary office in St. Louis.

I have tabulated the deaths of bilious fever, enteric fever and deaths in which typhoid is assigned as the cause and which I have not included in any of the other tables. Deaths from typhoid-pneumonia were variously recorded as typhoid-pneumonia and pneumonia and typhoid. All these deaths I recorded in a similar table headed "typho-pneumonia deaths at St. Louis."

The tables are as follows:

7840 Chart No. 11, bilious fever deaths.

7841 Chart No. 12, enteric fever deaths.

7842 Chart No. 13, deaths in which typhoid was the cause.

7843 Chart No. 14, typhoid-pneumonia deaths.

Q. Mr. Lochridge, state whether or not in your examination of the mortuary records, and in obtaining the deaths recorded from the various diseases heretofore referred to, you tabulated those deaths according to the results of the disease in the seven respective sanitary districts of St. Louis for the years 1896 to 1903, inclusive?

A. I have tabulated the typhoid fever deaths in the City of St. Louis according to the residence address in which the patient died for the years mentioned, in the following charts:

7845–52 (inclu.) Chart No. 15, typhoid fever deaths by sanitary districts.

These charts show, first, that there were 40 typhoid deaths in the hospitals of St. Louis during 1896, of which it was not possible to transfer the deaths to the proper residence districts of the deceased in 21 cases. In 1897, 20 of the 35 hospital deaths from typhoid fever could not be referred. In 1898, 16 of the 26; in 1899, 11 of the 21; in 1900, 4 of the 36; in 1901, 7 of the 55; in 1902, 6 of the 67, and in 1903, 3 of the 75 could not be referred back to their residence district. * * * Since the year 1900 the distribution throughout the 7 sanitary districts has been very uniform. When we consider

the deaths occurring in the hospitals and referred back to their respective districts, there is no district in which there was an unusual number of deaths when compared with other districts since 1900.

The distribution in the various districts has been quite uniform since that time, such as might be expected if the cause for the typhoid were one which would be equally applicable to all of the citizens of the city in the way that pollution by water is applicable.

I have made similar charts showing the deaths from malarial fever in St. Louis for the different years.

7856–63 Malarial charts from 1896 to 1903, inclusive.

The tables indicate the distribution during the year in the city and the increase in malaria from year to year begins between the years 1896 and 1903, which shows that the distribution in these
7864 districts is not as uniform in the city as in the case of death from typhoid fever.

7865–72 I have prepared charts from typho-malaria.

Typho-malaria charts from 1896 to 1903, inclusive.

These tables show the total number of typhoid fever deaths in each of the seven sanitary districts in each month for the eight years mentioned. The distribution is here, as in the case of malarial,
7873 less uniform than the distribution of the typhoid fever deaths.

I have prepared charts of typhoid fever deaths tabulated according to the age at the time of the death, and at the month of the year, which charts are as follows:

7874–81 Charts, typhoid fever deaths from 1896 to 1903, by ages.

From a study of these charts, which give the data in regard to the age and time of the death from typhoid fever in St. Louis during these eight years, it will be seen that a large proportion of the deaths occurring between the ages of 11 and 50 and the ages of 6 and 60 will include practically all of them. The number of children dying of typhoid, of those under 6 months or from 6 months to 1 year, is the same in the first four years as in the last.

Q. What do these charts show with reference to whether or not there has been an increase in typhoid fever in St. Louis for the four years subsequent to the opening of the canal, in January, 1900, compared with the four years immediately prior thereto?

A. It not only shows the increase in number, but also the increase under each of the ages, and also by the season of the
7882 year. The increase in any season can readily be seen from this chart. It will be noted that there is a considerable increase during the winter months, as well as a somewhat less increase in the summer months.

7883 I have prepared similar charts for remittent fever for the years 1896 to 1903, inclusive.

7884–91 Chart of remittent fever deaths according to age from 1896 to 1903.

In all of these tables the variations in the number of deaths from this cause will thus be seen to be in the column of children under 3 or people above 61 years of age, or perhaps during the ages ordinarily considered as typhoid ages, and indicated on the typhoid charts both before the opening and since the opening of the canal, as typhoid ages remain about constant.

7892 These charts also show the seasonal distribution of the remittent fever deaths.

7893 I have prepared charts from the deaths from intermittent fever from 1896 to 1903, inclusive, in which deaths from this cause

7894–7901 are tabulated according to age, which charts are as follows:

Charts of intermittent fever, 1896 to 1903.

The total number does not vary materially before and since the opening of the Drainage Canal, with the exception of the

7902 year 1899, in which there are nearly twice the number recorded for the other years.

I have prepared similar charts of typho-malaria for the years 1896 to 1903, inclusive, wherein the deaths are tabulated ac-

7903 cording to age, which charts are as follows:

Charts of typho-malarial deaths from 1896 to 1903.

7904–11 I have prepared charts of malaria and malarial fever tabulated according to age, which charts are as follows:

7913–20 Charts of malaria and malarial fever from 1896 to 1903.

The charts show in the same way the deaths by months and ages, and the total deaths by months and ages, for the year of the charts. The period of incidence of malarial fever or malaria is shown by these charts, and quite a decided increase since the year 1900 in the ages from 20 to 40.

7921 I have prepared congestive fever charts obtained from the same data and tabulated according to the ages and seasons for

7922–23 the same period, which charts are as follows:

Congestive fever charts from 1896 to 1903.

7925 I have also prepared bilious fever charts from the same data.

Bilious fever charts.

7927 I have prepared enteric fever charts in the same manner.

Enteric fever charts.

7928 During the eight years between 1896 and 1903, inclusive, there

were six deaths marked continued or continuing fever, two of these occurring in the four years prior to the opening of the canal and four occurring in the four years subsequent to its opening. There were so few of these that I did not plot them, but I will give the record of these cases. These six are the only cases of deaths occurring, so far as I could discover, from continuing or continued fever. There were no deaths marked "simple continued fever."

These tables show the largest number of deaths occurred between the ages of 11 and 50 and on either side of these ages; that is, under 6 or over 50, there are few deaths from typhoid fever. In the
7929 earlier years, from 1896 to 1899, inclusive, a much larger proportion of deaths occurred between the months of July and November. During 1901 and 1903 it will be seen that there are much larger numbers than the proportional increase in the months just referred to, during the months from January to June, and in the month of December, so that during the later years the typhoid fever deaths are scattered pretty generally through the years, there being a few more during the summer months than during the winter months.

I have prepared a chart with the caption, "Winter Typhoid, St. Louis."

* * * It will be noted that in the year 1898 a dotted line leaves the heavy black line, joining it again in 1901. This correction was made because it was found that a local epidemic of typhoid was present in the City of St. Louis at that time. The number of deaths during this particular epidemic in each of the sanitary districts was not in the proportion usually maintained, and all of the evidence which I could obtain indicated that typhoid deaths for these months were in part due to the localized epidemic. For this reason the average number of deaths for the three years prior were taken, and the difference between this average number and the recorded number was deducted and the tables for 100,000 living recalculated and plotted, thus showing that in considering these winter months the added deaths due to this local epidemic, there was no increase in the winter typhoid death rate in the year 1899, and that the rise was marked in 1900,
7931 even after deducting in the same way the deaths probably due to this local epidemic in January, 1900.

7932 Chart of winter typhoid.

Chart of summer typhoid.

7934 I have in the same manner as in the chart showing winter conditions, taken the average of the total typhoid deaths for the three years prior, and have deducted the difference between this number and the number recorded for the month of November 1899, which

are shown by means of the heavy dotted line, thus indicating this correction for the localized epidemic on the chart.

It will thus be seen that, eliminating the effect of this one localized epidemic in the one month, that the typhoid death rate per 100,000 was not materially different in 1898 than 1899, but that a sharp rise is indicated for the year 1900.

I have prepared a chart showing the comparison of typhoid
7935 deaths in St. Louis for the winter and summer months prior to and since the opening of the Drainage Canal.

7936 Chart, comparison of typhoid deaths, winter and summer.

Q. From what source did you get the data upon which the last three charts were based, and which you have read in evidence?

A. This data was obtained by me from the records in the office of the clerk of the mortuary office, the mortality department
7938 of the City of St. Louis. I hae already read it in evidence.

Q. Mr. Lochridge, state the character in a general way of the examination that you made of the records in the mortuary office of the Health Department of the City of St. Louis in securing this data, and the mortuary records of the various diseases named?

A. I got the date of death, the name, the age, the residence in the city, and, if a death occurred in the hospital, the name of the hospital and the residence address from which the case had been transferred to that hospital, the ward and sanitary district given in this record the contributing cause of death named by the physician in every case of typhoid, typho-malaria, remittent, intermittent, congestive, continued, enteric, bilious fever, typhoid-pneumonia, or any deaths referred to by me. In doing this I examined the cause of death of every person dying in the City of St. Louis during the eight years from 1896 to 1903, inclusive.

Q. From what book or books in the office of the mortuary clerk did you obtain the data read; state how the books from which this data was obtained are made?

A. In order that a burial certificate may be issued the attending physician, or the coroner must bring to the mortuary office, a certificate of death showing the age and cause of death in each case. These certificates contain the age at death; also quite frequently the duration of the illness, the contributing cause and any remarks of the physician, and the residence and place of death of the deceased. The data from these certificates is then copied into their books, which are so ruled that each part of the data referred to is recorded in a separate column, this record being made by an assistant. Every death is then checked by the mortuary clerk. These books are then regarded by

them as the official record of those deaths, and any certified
7940 copies of deaths made to insurance companies or others are made from these books. These books are all kept with great care in a large vault.

Q. These books about which you have spoken in your last answer are the only mortuary records in the mortuary office of the Board of Health in the City of St. Louis, are they not, from which the data you obtained can be secured?

A. I believe they are. I was so informed.

Q. State whether or not the officer in charge of these books permits them to be taken from the office?

A. He will not.

Q. State whether or not these records as observed by you while working on them were in daily use?

7940 A. These records were in daily use.

Q. State whether or not you made inquiry as to whether or not and how these books may be taken out of the mortuary office, if at all?

A. I made such inquiry and was informed by the clerk of the mortuary office that such records cannot be taken by any one from the office; that if it was necessary to use them at any time outside, permission must be secured from the commissioner and subpoena issued and a regular member of the staff must always accompany them.

Mr. JEFFRIES: I will state for the benefit of the court that I would be very glad indeed to introduce this book in evidence, but on account of its public importance I am unable to do so on account of it being absolutely necessary that it remain in the archives of the mortuary office. I will also state to the counsel of the defendant that, if he desires, I will have this book produced before him, subject to his inspection if it is possible to do so.

Mr. TODD: In reply would state that counsel for the defendant desires nothing, as complainant has the burden of making out their own case according to legal evidence.

Q. How many of these books are there, as well as you remember?

A. I should think eleven or twelve.

7941 Q. How large are they; about how many pages?

A. Why, several hundred pages. They are perhaps four inches thick and the height of the page over two feet.

Q. Have you your original transcript from the records showing the data which you have introduced in evidence, together with the name of the deceased?

A. I have.

Mr. JEFFRIES: I desire to offer these as complainant's rebuttal exhibit for identification, which said exhibits are produced
7942 and marked by the commissioner "Complainant's Rebuttal Exhibit 1" for identification.

The deaths from typho-malaria follow more nearly the age periods of the typhoid fever than do those of either intermittent or remittent fevers. The number of deaths from typho-malaria is practically the same during the four years prior to the opening of the canal and the four years subsequent. * * * The deaths from malaria and malarial fever appear to be distributed about proportionately over the various ages of the different years plotted. There has been a marked increase in malaria and malarial fevers during the last few years, with the exception of two years, when the congestive fever list was low, the variation was due to the deaths under these younger ages, or of quite old people.

The number of deaths from bilious fever is in all cases without variation in the number, being either in the younger ages or in the older ages, and, as mentioned before, there has been no increase in the typhoid fever deaths in these ages to correspond with the decline in the bilious fever deaths of those ages.

Calculation showing the increase of population in St. Louis caused by the World's Fair, calcuated upon the mortality rate
7945 of typhoid fever per 100,000 inhabitants, enabling the mathematician to make an increase in St. Louis of 681,500 people,
7946 or an increase of more than the entire present population of the city.

7947 I am familiar with the experiments conducted by Profs. Jordan, Zeit and Russell.

Q. State whether or not, in your opinion, the results of these
7948 experiments represent or simulate natural conditions.

A. I do not think they do.

Q. Why?

7949 The answer follows.

I have read the evidence of Messrs. Jordan and Burrill upon the colon test, and experiments made by them and introduced in evidence. They do not show by any means a total elimination of the coil. Of course, there is a reduction, but there is no point represented where there is an elimination of the colon as is shown directly from the tables. These colon determinations are always subject to a good many conditions, especially the presence of streptococci, or

7950 perhaps even other bacteria present in the water. These very frequently mask the coil so that any reaction of the coil is not given.

I do not believe that any considerable number of deaths have been classed as typhoid since the opening of the drainage canal which without the use of the Widal test reaction would have been placed in the column entitled remittent, intermittent, typho-malaria, congestive and continued fever.

The variations in the number of people dying from the fevers I have diagramed has been of people of ages when there are the least number of deaths from fevers, and there are more of those
7951 at the age of typhoid susceptibility in the years since 1900 than at any other time during the eight years examined.

CROSS-EXAMINATION.

By Mr. Todd.

Q. In preparing the tables which you have introduced in evidence, were you assisted in going through the entire record by any official of the office of the Health Department of the City of St. Louis checking up the deaths with you, or did you do it alone?

A. All the work was done in the office of M. Smyth, the clerk of the mortuary office. He looked over all that I had copied and I asked him to check certain places, which he did, finding the number the same. I did every bit of the work myself, and was assisted only in the way mentioned.

MR. TODD: I move to strike out all the evidence of this witness in regard to the records of the mortuary office of the
7952 Board of Health of the City of St. Louis, for the following reasons: That the public records of the mortuary office, if ad-
7953 missible at all, are the best evidence; that it is not the proper way to prove a public record, etc.

MR. JEFFRIES: * * * I desire to say further that at the time complainant introduced this evidence, as stated a few moments ago, no attempt upon the part of complainant was made to use the mortality records upon any disease other than typhoid fever, complainant believing at that time that death from no other disease would be brought into this controversy, or had any part in it. * * * Now, as to the introduction of the original records, I desire to state that it is impossible to introduce them in evidence, and that if they want copies to place before the court it would be necessary for the court to spend months in making the determinations themselves, be-

cause of the fact that all deaths from any character and from all diseases are recorded in these books, and that they, therefore, secured this data in the most practicable and best manner possible.

MR. TODD: In regard to counsel's statement the argument of convenience does not obviate the legal objections made by defendants to the admissibility of the testimony, and defendants have a right to demand that evidence in order to be competent must be legal.

MR. JEFFRIES: Mr. Commissioner, will you issue a subpoena duces tecum for Mr. Smyth, mortuary clerk, for the mortuary record containing the deaths from typhoid, typho-malaria, intermittent, remittent, congestive, simple continued, bilious and malarial fevers for the years 1896 to 1903, inclusive?

Q. Have you ever made any experiments on your own account with the parchment, celloidin and agar blocks?

A. I have not.

Q. Have you ever conducted, individually and on your own account, any experiment upon the longevity of the typhoid fever bacilli under natural conditions?

7954 A. No, sir.

Q. Have you made any study of the diagnosis of fevers?

A. No, sir.

Q. Are you acquainted with the number of doctors in the City of St. Louis who employ the Widal test?

A. I do not know the number that employ that test.

Q. Have you any means of knowing about the number of doctors in St. Louis that employ that test?

A. I do not know where the records could be obtained in that line.

Q. Are you acquainted in St. Louis among the medical fraternity except those who have testified in this case?

A. No, sir.

Prof. Wm. T. Sedgwick's explanation of why he used in his
7955 testimony in this case the percentage mortality method as a basis of determining the increase or decrease of typhoid fever
7957 deaths in the City of St. Louis.

Chart showing the two methods; St. Louis and Boston.

7958 I think the quotation which I made from memory was nearer the original, which I will now read from the report referred to by myself, and I presume Prof. Jordan. * * * "There is no river in the United Kingdom long enough to secure the oxidation and destruction of any sewage which may be discharged into it, even at its source."

I may say that I am not surprised that Prof. Jordan had diffi-
7959 culty in discovering this precise quotation, inasmuch as the book is a large one and is not at all well arranged.

I may say further that the popular version of the statement made by the commissioners is simply that "There is no river in England long enough to purify itself." It is easy to see how this shorter version has arisen, and if it were simply made to run, "There is no river in the United Kingdom long enough to purify itself," I believe that it would sufficiently represent the doctrine of sanitary science to-day.

I am acquainted with the experiments made by Messrs. Jordan, Zeit and Russell.

Q. State whether or not you are able, from the determinations made by you in the above connection, to formulate an opinion as to the longevity of the typhoid organism contained in those waters.

A. I should not be able either to form or to formulate a comprehensive opinion from these experiments alone. It is clear, of course, that as shown in these experiments the germs survive a certain length of time, but I should be unable to conclude from the experiments that under different conditions typhoid fever germs might survive for longer times. The experiments appear to me to have been very ingenious and interesting, but not by any means conclusive upon the whole subject of the longevity of typhoid fever germs in moving bodies of sewage or water.

I do not see how it is possible in the present stage of bacteriology to devise any series of experiments which will accurately and completely imitate the infinitely various conditions of running streams, and particularly streams such as the Chicago River, the Drainage Canal and the Illinois River, subject, as these are, to an endless variety of alterations in their physical, chemical and bacteriological conditions. * * * Furthermore, the result of these experiments, BROADLY SPEAKING, indicate a considerably shorter period of life for the typhoid fever germ in sewage and water than has been found by the majority of previous investigators. My own opinion is that a greater number of experiments conducted for a longer time and under different conditions would not fail to show that typhoid fever germs may and do live in sewage and running streams a very much longer time than was found in these experiments. I should not say that these experiments failed to represent natural conditions any further than many experiments must necessarily fail to imitate natural conditions. I mean by that that these experiments were, undoubtedly, well planned and well conducted, but it is easy to suggest

a great number of points in which they do nevertheless fail. * * * Some other matters have already been mentioned by witnesses for complainant in rebuttal, such, for example, as the fact that the germs in the several experiments were anchored at fixed points instead of being allowed to float down the stream with a particular body of water. * * * The sewage discharge from a city at night is a very different body, chemically, from that discharged by day. * * * The trouble is that in trying to fix the longevity of typhoid fever or any other microbes we are dealing with extremely sensitive and almost infinitesimal organisms, which we have only within the last few years learned to recognize at all, and have not yet by any means learned to know thoroughly.

I believe, therefore, that while the experiments of the experts of the defendants are interesting, ingenious and important in
7962 the science of bacteriology, they should not be allowed to have too much weight in determining the issue in this case.

It is my opinion that their results are so far out of harmony with the results of previous investigators, and so contrary to the prevailing opinion upon this subject, which forms the basis of the practice of sanitarians and engineers in forming their opinions concerning the availability of polluted streams for drinking and other domestic purposes, as to throw grave doubt upon the results, and, therefore, upon the conclusions to which these naturally lead.

I have read the testimony of Prof. Mason, and taking into consideration the distance between the two cities and the time required for the passage of typhoid fever germs from Chicago to St. Louis, and taking into consideration also the character of the drainage canal and the Illinois River, and taking into consideration that the water drawn from the Mississippi River at the Chain of Rocks is subjected to extensive sedimentation, I should not expect to find any close correspondence between the details of the typhoid fever curves of the cities of Chicago and St. Louis over such periods. * * *

I should therefore expect to find a correspondence between the prevalance of the fevers in the two cities in general, and, BROADLY SPEAKING, only when considerable periods were dealt with. * * * I am, therefore, not surprised to find that the curves of Prof. Mason do not indicate any conspicuous and constant relation between waves of typhoid fever in Chicago and similar waves in St. Louis. I do believe, however, that by taking long periods and averages we ought to see and do see a definite connection, as, for example, when comparing typhoid fever in the years following 1900
7964 with those preceding that date.

The colon test applied by Prof. Jordan and Prof. Burrill in the waters of the Illinois River, while they show a very great decline in the number of these organisms, present in the lower regions of the river at the time when the specimens examined were taken in those particular specimens, do not, in my opinion, enable anyone to form a correct opinion as to the presence or absence of typhoid fever germs in the waters of that river at these points. * * * It is not a sure and perfect test for the colon bacillus at all time, because experiments have shown that these organisms sometimes fail to make their appearance in the tests applied, even where it is proven to be present by a further study of the same experiment. * * *

I am, therefore, of the opinion that while the experiments of Profs. Jordan and Burrill throw great light upon the process of bacterial purification going on in the Illinois River, they do not by any means establish the fact that typhoid fever is completely or effectually removed from the waters of that river before it empties into the Mississippi at Grafton.

I have examined the tables introduced in evidence by Mr. Lochridge. The typhoid fever deaths taken by themselves, and alone, show a marked annual increase during the last four years; that is to say, since the opening of the Chicago Drainage Canal. This increase, moreover, is not only considerable from year to year during this period, but is much more marked than it was during the preceding period. In fact, during the four years, 1896 to 1899, inclusive, typhoid fever in the City of St. Louis may be said to have been stationary, or very nearly so, and not at all excessive, the annual death rate from typhoid fever measured either by percentage mortality or by comparison with the total population, having been such as,
7966 broadly speaking, prevailed only in cities having good water supplies. * * *

I will, however, say before leaving them that they appear to me to prove beyond a reasonable doubt that the typhoid fever increase in the City of St. Louis since January, 1900, is not due to any transfer of deaths from remittent, intermittent, typho-malaria, congestive and simple continued fevers into the typhoid fever group.

* * * Mr. Lochridge has made a correction, indicated by dotted lines upon some of the charts, for the localized epidemic of typhoid fever which occurred in November and December, 1899, and the deaths from which continued, apparently, into 1900. This epidemic, as I have taken pains to inform myself by inquiry of physicians in different parts and otherwise, was localized in the west central portion of the city, so much that in my judgment it could not

have been due to the general pollution of the public water sup-
7968 ply. I believe that it was due to milk, but I am unable to state this positively.

7970 Effect of world's expositions as affecting typhoid cities discussed.

Q. Doctor Zeit in his testimony, along with other witnesses for the defendant, attributed times of extensive destructive effects upon typhoid fever germs in sewage and sewage polluted water to the toxic products of the saprophytes in sewage. State whether or not bacteriologists and epidemiologists agree with him as to these facts.

A. Unquestionably some would agree with him; others, like myself, do not accept this view, and against Dr. Zeit's theory I may quote the following experiment made by myself and one of my students as long ago as 1893. In this experiment we undertook to test the very point under consideration. A portion of the sewage was freed by filtration from all microbes present, whether saprophytic or parasitic. The filtrate was proved to be particularly free from such germs, but was otherwise ordinary sewage; that is to say, it contained the toxic products, if any, of the saprophytes which it contained in abundance, and which had been removed by filtration. * * *

These experiments satisfied me that whether or not typhoid fever germs ultimately disappear in sewage they are not readily destroyed by the toxic products of saprophytes, and are liable to live longer in their presence.

I have obtained from these tables (Streams Examination and Prof. Long), and other data, a much better knowledge of the process of chemical and bacterial purification going on at certain times and seasons in the Illinois River, but I have failed to discover any reason for changing the opinion which I expressed in my examination in chief a year ago, namely, that a large part of the increase of the typhoid fever in the City of St. Louis since the first of January, 1900, has been due to the presence of deleterious elements contained in the public water supply, and derived from the unpurified sewage of the City of Chicago. The additional information which I have gained on the history of typhoid fever and other fevers in St. Louis, especially during the last year, has only served to strengthen that opinion.

7973 CROSS-EXAMINATION,

By Mr. Todd.

Q. Have you done any work in bacteriology yourself in recent years?

A. If you mean personal work in the laboratory with the bacteria themselves, I shall have to answer not much, although I am constantly in touch with the subject, partly by teaching some portions of it and partly through my several assistants and graduate and special students, all of whom are actively engaged in personal work on the subject.

MR. JEFFRIES: I rest.

MR. TODD: I offer in evidence, on behalf of respondents in sur-rebuttal, the annual reports of the Health Commissioner of the City of St. Louis for the years from 1890 to 1903, inclusive,

7974 and ask to have them marked "Respondents' Sur-Rebuttal Exhibit 'A.'"

On behalf of the State of Illinois and the Sanitary District of

7975 Chicago, defendants in this case, I rest the case on behalf of the defendants.